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JOURNAL OF CHEMICAL EDUCATION

for December, 1937

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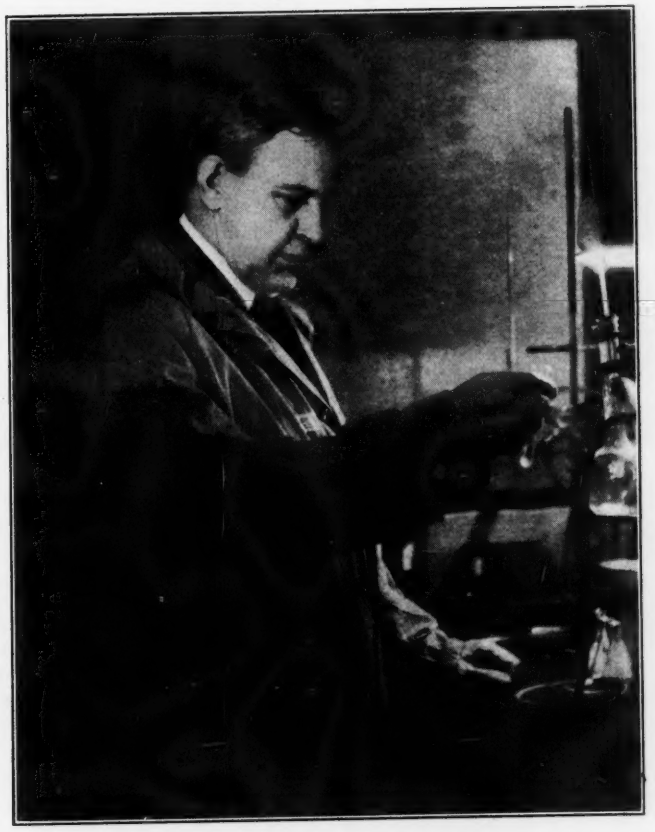

VLADIMIR N. IPATIEFF (1867–)

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EDITOR'S OUTLOOK

EXCHANGE OF PLEASANTRIES BETWEEN READER AND EDITOR. Our thanks to a reader who gives us a pretext for expanding upon a favorite topic.

"Since you expressed pleasure at receiving comments on your editorials your blood is on your own head. I refer to the editorial in the October issue.

"I think the idea of discussing political and social questions is fundamentally sound. The discussion must be rational to be useful.

"You make three statements which I suggest you consider further.

"'The average man (that is to say the fool)' . . . I do not believe that the average man can be justly called a fool. If he is it would seem advisable to stop trying to educate him and stop trying to make democracy work.

"'. . . politicians, being for the most part confidence men of the first and dirtiest water.' This statement repeats a carefully fostered idea. It would be equally true if for politicians one substituted business men, newspaper men, or people. What will politicians do for votes that business men will not do for profits or newspaper men for circulation?

"Perhaps you are right that a man has no 'right to a job or to public charity'. No more has he a 'right' to free speech or to own property. However, there is more involved than the 'right' of a man who loses his job to live. A system of mass production requires mass consumption and mass purchasing power. If mass purchasing power disappears because enough individuals have no 'right' to money, with or without work, the whole system collapses."

We fear that this reader, at least, suspected us of calling names. Doubtless he regards "fool" as a very hard word, and would apply it, if at all, only to the abysmally irrational and incompetent. On that basis it would be both unjust and grossly inaccurate so to label the average man. The average man is normal—any psychologist or sociologist will tell you so. If folly be defined as subnormality, obviously the average man is acquitted by definition. On the other hand, if folly be compounded of wishful thinking, emotional response to stimuli, gullibility, lack of foresight, unenlightened self-interest, and the like, the average man stands convicted beyond reasonable doubt in any fair-minded court. We even admit to a touch of the disease, ourselves, and what could be handsomer than that?

Since "democracy" (we presume democratic government is meant) has its roots in the great mass of average men it follows that democratic government is always inefficient, wasteful, and less than omniscient, often oppressive of minorities, and sometimes dishonest. It does not follow, however, that imperfection is synonymous with failure. Any other known form of government (or anarchy) seems to us to have these defects in greater measure, or worse ones. Fortunately, fools are seldom unanimous, and never consistent, in their folly. Errors are usually corrected (indeed, overcorrected) in time.

"To educate" also needs definition. If an educated man be a gentleman and a scholar, the average man can't be educated, and nobody seriously tries to educate him. However, if education consists in teaching him (or helping him to learn) a few things that may make him more of a help and less of a menace to himself and his fellows, then it seems possible, and we should never give over the effort.

To suggest that business men in general are no better than politicians in general is, of course, merely to excuse the pot by calling the kettle black. Purely as a matter of personal opinion it doesn't seem to us to be so. (Yes, we read "A Hundred Million Guinea Pigs," too.) The few business men we know personally, and the many with whom we do business in one way or another in the course of a year seem, on the whole, to be pretty decent fellows. We can recall scarcely a half-dozen instances in a lifetime when we were gypped in a business deal—and then only when we asked for it by bargain hunting. But we can't read a daily paper of whatever date on political persuasion without discovering evidence that, as a citizen, we have been, and are being, gypped by the politicians. If it be maintained that the business man only appears better because he can't get away with so much, the logical conclusion is that a field of activity in which one can get away with murder will naturally attract a high proportion of those who have a disposition to do so.

As we see it the rights to free speech and to property ownership exist in this country merely because we have mutually agreed to respect those rights among ourselves and to take coöperative action against anyone who does not respect them. It is much more difficult to establish the right to a living on an analogous reciprocal basis. Too often one of the would-be parties to the contract can offer no consideration that the other prospective party wants or can use. The proposed solutions of this vexatious problem usually beg the question by abandoning the basis of reciprocal contract and resorting to the right of seizure. It is to this that we object.

As a unit in the present economic system we recognize the expediency of seeing to it that no competent and willing worker starves. As a citizen we feel a humanitarian (or, if you will, moral) obligation to assist in seeing to it that no one does. At present we can find no better solution of the problem than for the more fortunate of us to agree among ourselves to assume this responsibility. We would like to insist, however, that the beneficiary of the contract is not a party to it, and should not become one until some way is found whereby he can enter it on a reciprocal basis.

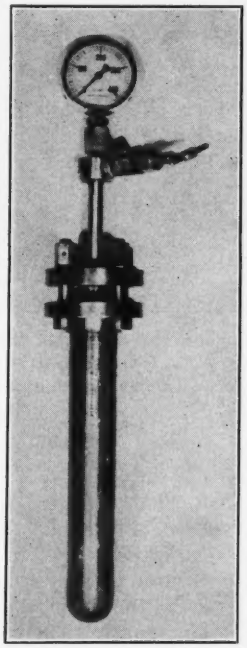
VLADIMIR IPATIEFF

ARISTID V. GROSSE

Research Laboratories of the Universal Oil Products Company, Riverside, Illinois

THE seventieth birthday anniversary of Vladimir Ipatieff falls on November 21, 1937. As this note is written the Chicago Section of the American Chemical Society is planning to celebrate this occasion at its November meeting. It is, therefore, highly appropriate that a biographical sketch should appear at this time.

Ipatieff's birthplace is Moscow, Russia. He received his education in military schools, and in 1892 graduated from the Michailow Academy of Artillery in St. Petersburg. His chemical education was mostly self-imparted with the aid, mainly, of Mendeléeff's "Principles of Chemistry" and home experimentation in a small laboratory.



IPATIEFF BOMB

After remaining several years at the Academy, Ipatieff went in 1896 to study abroad. He was accepted at the laboratory of Adolf von Baeyer in Munich, thanks to the recommendation of Schischkow, a personal friend of the latter. At that time von Baeyer's laboratory was at the height of its glory. The old master, assisted by Johannes Thiele, famous for his theory of partial valences and W. Königs, well known for his researches on alkaloids, was recognized as the leader of organic chemistry. A host of young, eager students, among them Richard Willstätter and Moses Gomberg, were assembled here. As a result of Ipatieff's stay a joint paper with von Baeyer on carbonic acid was published.[1]

Early in 1897 Ipatieff went to Paris to study under Paul Vieille, well known for his discovery of smokeless gunpowder, and Emile Sarrau at the Laboratoire Centrale des Poudres et Salpetres.

On his return to St. Petersburg he continued his studies on unsaturated hydrocarbons, originally started at the suggestion of Professor A. E. Favorsky. His first important and original contribution was the determination of the constitution of, and the synthesis of, isoprene, the mother hydrocarbon of natural rubber.[2] His interest in unsaturated hydrocarbons led him, in 1900, to investigate Thiele's method for the preparation of 1,3-butadiene by the pyrolysis of isoamyl alcohol. He immediately noticed a profound influence of the walls of the reaction tubes on the nature of the pyrolytic reactions, and this observation led him on a trail of highly important contributions to chemistry. Here Ipatieff's peculiar and sharp chemical instinct manifested itself for the first time in a particularly striking way. He began a series of investigations entitled "pyrogenetic contact reactions of organic compounds," published simultaneously in the *Journal of the Russian Physical-Chemical Society* and the "*Berichte*" of the German Chemical Society.[3]

Herein he recognized, before any of his contemporaries the possibility of directing the pyrolytic decomposition of organic compounds toward definite desired products by means of suitable catalysts. For instance, metals, giving easily reducible oxides, *e. g.*, copper and zinc, catalyze the dehydrogenation of alcohols to aldehydes and ketones according to the general equations:

$$RCH_2{\cdot}OH \rightarrow RCH{:}O + H_2$$

or

$$R'(R'')CH{\cdot}OH \rightarrow R'R''C{:}O + H_2$$

On the other hand, difficultly reducible oxides of metals, forming easily decomposable hydrates, *e. g.*, alumina, are able to dehydrate alcohols selectively and quantitatively into olefins and water according to the scheme:

$$C_NH_{2N+1}{\cdot}OH \rightarrow C_NH_{2N} + H_2O$$

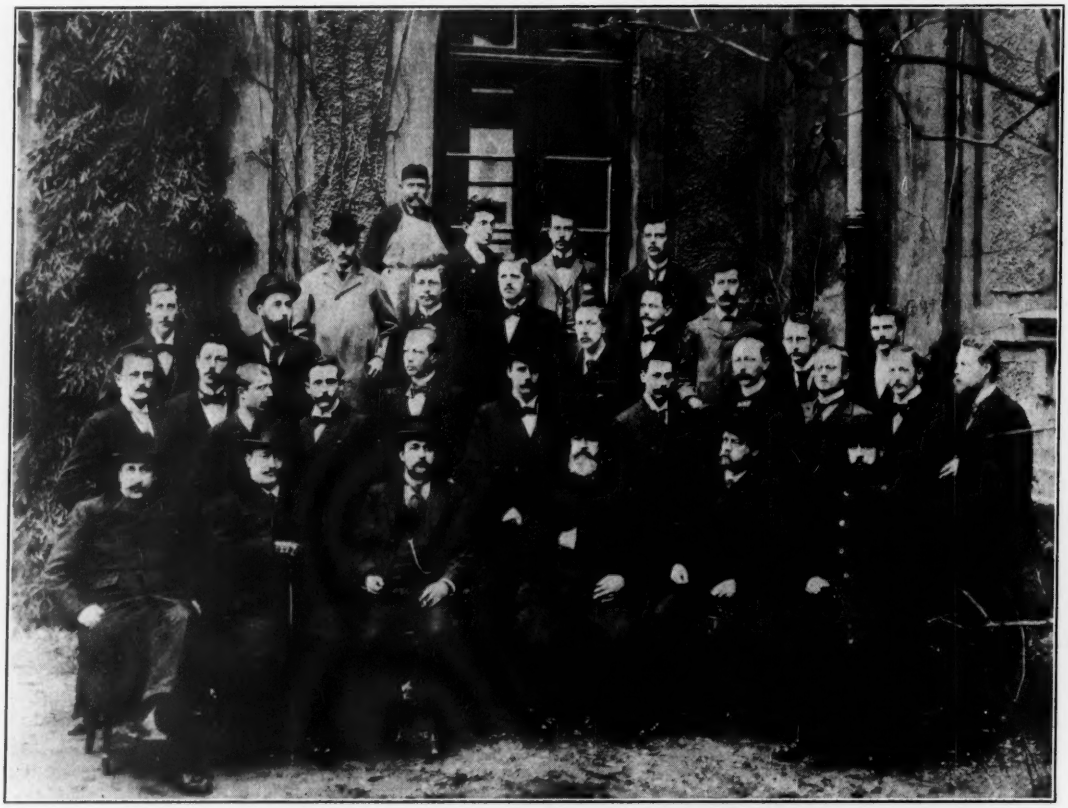
In order to realize the great theoretical and practical importance of these results, one must remember that at that time the general opinion among chemists was that pyrolytic reactions proceed at random, leading to all sorts of decomposition products, such as carbon, hydrogen, methane, ethylene, water, carbon monoxide, carbon dioxide, etc., and that they cannot be controlled.

In the attempt to study the reversibility of some of his newly discovered reactions, Ipatieff became highly interested in the introduction of high pressures as a new factor in chemistry. After a number of attempts, he finally developed, in 1903–04, his famous high-pressure bomb with the simple ring closure (see figure), which was destined to become the test-tube of high-pressure chemists. Working with pressures up to 500

[1] A. VON BAEYER AND V. N. IPATIEFF, *Ber.*, **29**, 2796 (1896).

[2] V. IPATIEW AND N. WITTORF, *J. prakt. Chem.*, [27], **55**, 1 (1897). V. IPATIEW, *ibid.*, **55**, 4 (1897).

[3] V. IPATIEFF, *Ber.*, **34**, 596, 3579 (1901); **35**, 1047, 1057 (1902); **36**, 1990 (1903); etc.



GROUP IN FRONT OF BAEYER'S LABORATORY, MÜNICH, 1896

Reading from right to left in the front row, the first four are, in order, V. Ipatieff, W. Königs, Adolf von Baeyer, and Johannes Thiele. Second from the right in the second row is R. Willstätter, and third from the right in the third row, Moses Gomberg

atmospheres and temperatures up to 500°, Ipatieff was able to demonstrate the fundamental and general importance of pressure in chemical reactions. Ipatieff's studies on dehydrogenation naturally brought him in close contact with catalytic hydrogenation of organic compounds, a field which was being brilliantly developed at the same time by the Frenchmen, P. Sabatier and J. B. Senderens. Hydrogen under high pressure allowed the reactions to proceed much more rapidly, and, in a number of cases, farther than under the conditions of Sabatier. The further development of these pioneering experiments in the hands of Friedrich Bergius, assisted by the enormous technical and financial resources of the I. G. Farbenindustrie finally led to the modern process of liquefaction of coal.

A continuation of his catalytic studies led Ipatieff in 1912 to demonstrate in a striking example the promoter action[4] of catalysts on one another. The simultaneous use of nickel oxide as a hydrogenating catalyst, and alumina as a dehydrating catalyst, allowed him to obtain in one step, under much milder conditions than theretofore, the hydrocarbon isocamphane from the alcohol borneol.

The World War interrupted Ipatieff's scientific work. Soon after the beginning of the War, he was put in charge of the chemical defenses and ammunition supply of his country. The years of the Revolution and Civil War, 1918–20, were a period of inactivity and gloom. In 1921, Lenin, himself, called Ipatieff to take part in the reconstruction of the country. In the position of Director of the Chemical Administration of the Supreme Economic Council of the U. S. S. R., Ipatieff took an extremely active part in building up, practically "from scratch," the chemical industry of Russia. In 1927 he organized the Institute of High Pressures in Leningrad. There, for the first time with a large number of co-workers he was able to push his high-pressure experiments into the field of inorganic chemistry, besides continuing his organic studies.

His frequent journeys to different European countries, mainly Germany, brought him in contact with an ever-increasing number of personalities in different

(*Please turn to page 594*)

[4] V. IPATIEFF, *Ber.*, **45**, 3205 (1912).

HENRY LE CHATELIER: 1850 *to* 1936*

ALEXANDER SILVERMAN

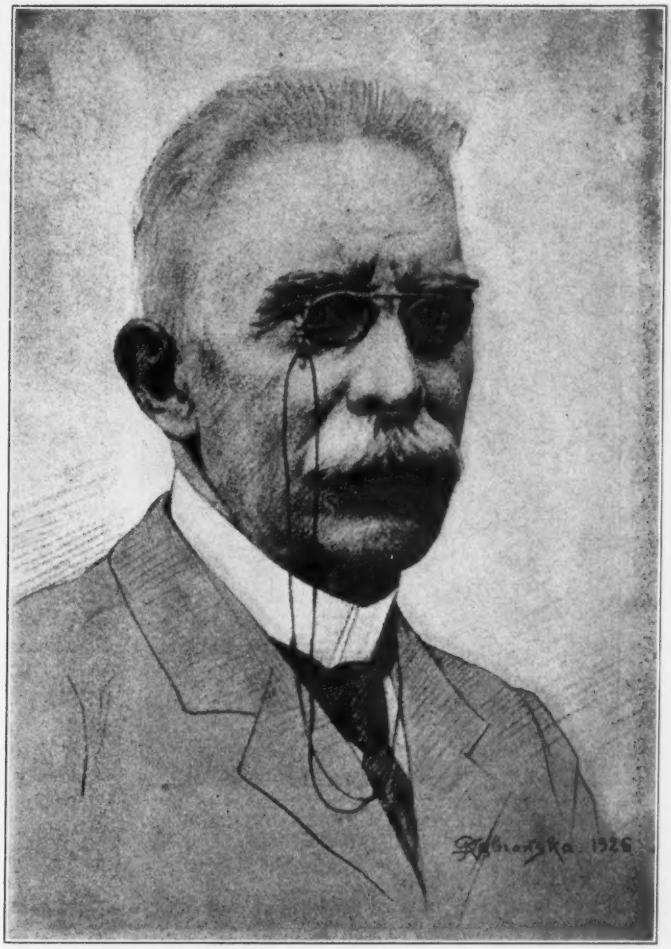
University of Pittsburgh, Pittsburgh, Pennsylvania

HENRY LE CHATELIER was born in Paris, France, October 8, 1850. He was the son of Louis Le Chatelier (1815–1873) who was inspector General of Mines for France. The father was one of the engineers who created the French National Railways in whose interests he worked from 1855 to 1868. He was consulting engineer to bankers who financed the railway systems, not only of France, but also of Spain, Austria, and Russia. He was an associate of H. de Sainte-Claire Deville in the establishing of the first aluminum industry of France, and of Sir William Siemens with whom he constructed the first open hearth steel furnace.

The mother, Elisabeth Durand, came from a family of artists and scientists which included sculptors, engravers, geographers, etc. She was an ardent Catholic and through her own early environment and her love of poetry fostered in her son that appreciation of art and letters which was evident throughout his life. The mother was a rigid disciplinarian and so directed the lives of her children that they would not only prove conscientious as students, but appreciate physical well-being and rest, as well. Henry arose early each morning and prepared his lessons. Later, on entering the École Polytechnique (1869), he would go to his father's study each morning at 7:30 and review his lessons for the day. He learned to respect law and order, and he enjoyed the almost military attitude in the École Polytechnique.

Even his grandfather was a factor in determining Henry's career. He operated lime kilns, and during his vacations Henry would visit the grandfather's plants where he acquired his first interest in mortars and cements.

While Henry was at the École Polytechnique he assisted his father and, as the latter received visitors who were interested in the fields of agriculture, medicine, chemistry, and metallurgy, the son gained valuable experience. To observe the analytical mind of his father and the manner in which he solved problems was helpful. Not only would the father teach him mathematics, but he would provide him with essays on chemistry which had been written by Sainte-Claire Deville, Debray, Dumas, Chevreul, and others of his associates. The boy read the reports of the French Academy of Sciences. He was permitted to assist his father while the latter helped to create the aluminum industry, and thus gained much first-hand information about this new metal. Sainte-Claire Deville permitted the lad to work in his laboratory and coöperated with the father in guiding the son's efforts. Henry Le Chatelier stated many years later that the influence of his father and the contacts with his father's associates were important influences in "shaping his career and establishing that reputation which he held as a chemist."



HENRY LE CHATELIER

* Contribution No. 350 from the Department of Chemistry, University of Pittsburgh. Presented before the Division of the History of Chemistry of the American Chemical Society, Rochester, New York, September 6, 1937.

While we are considering the father, the mother, the grandfather, and others who influenced Henry's career, it might be interesting to note that his own brothers and sister were likewise interested in science. His brother Louis was a bridge and railway engineer, and constructed steel plants. Alfred was an army officer and had much to do with the development of the French colonial empire. This brother worked on high temperature enamels. His brother George was an architect.

HENRY LE CHATELIER AS A STUDENT IN THE ÉCOLE POLYTECHNIQUE (1869–1871)

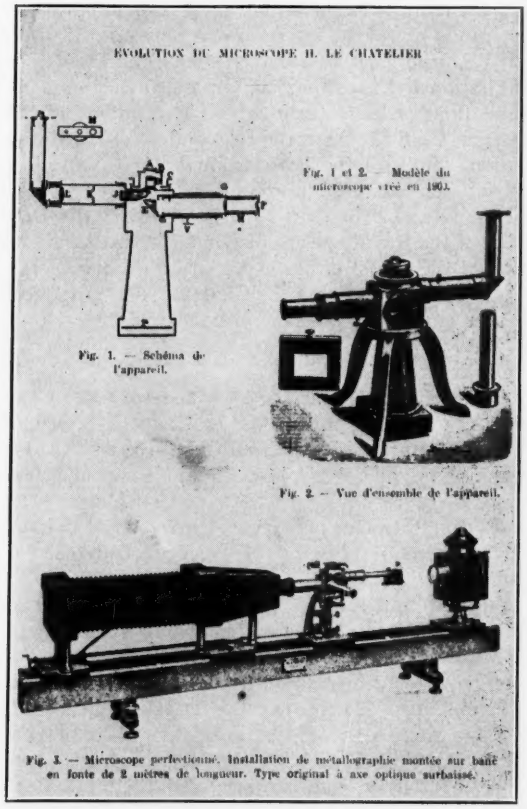
A fourth brother, André, the oldest of the children, worked with Henry in creating the autogenous welding industry and devised methods for the safe storing of liquid acetylene. He not only made studies on the resistance of metals to high temperatures, but devised metal lath, which is still in use. This substitute for wood possessed a much greater strength and was fireproof. The sister, Marie, married a Dr. Leroux who was a pediatrician.

Henry's early education was obtained in Paris where he attended a military academy for a short time and then entered the Collège Rollin, receiving the Bachelor of Letters in 1867 and Bachelor of Science in 1868. He entered the École Polytechnique in 1869 where his work was interrupted by the war of 1870. His studies were completed in 1872, and he registered as a mining engineer. In 1874 he was licensed to practice physical science. In 1877 he became Professor in the École des Mines. In 1882 he was lecturer in the École Polytechnique. In 1883 he became Professor in the Collège de France and later Professor at the Sorbonne. The degree of Doctor of Physical and Chemical Science was conferred upon him in 1887, when he became Professor of Industrial Chemistry and Metallurgy in the École des Mines. Until 1897 he devoted himself to the mechanics of chemical reactions, establishing the laws of chemical equilibrium and the displacement of equilibrium. He studied solutions. Applying thermodynamic values he was able to anticipate possibilities, instead of depending on trial and error methods and performing costly experiments which might result negatively. In 1889 he won the title of Chief Engineer and that year returned to the Collège de France as Professor of Inorganic Chemistry, remaining until 1908. Already in 1907 he had been appointed Professor of General Chemistry of the Faculty of Science of Paris. This title he retained until he became Honorary Professor in 1925. During the period 1908 to 1922 he directed the researches of more than one hundred graduate students, of whom twenty-four obtained the doctorate as his majors.

Le Chatelier was a reformer. He was not content with providing the descriptive material and facts which his colleagues presented, but constantly introduced theory and the newer ideas, presenting his own interpretation of fundamental principles and laws.

In the research field Henry Le Chatelier possessed great versatility. He is recognized chiefly for his contributions to thermodynamics and chemical theory. We are familiar with his principle on stress and strain which is coupled with that on heat advanced by van't Hoff. It is not strange that he should have accomplished the synthesis of ammonia from the elements in 1901, anticipating Fritz Haber, who is usually the only one mentioned in connection with the process. Henry Le Chatelier was interested in allotropy, especially in carbon, silica, and certain metals. He made extensive solubility studies, including dissociation. He studied the dissociation of gases at high temperatures and the combustion of gas mixtures, and applied the results to the utilization of fuels and the economics of furnace operation. Later he entered the field of explosives and indicated their use in mining operations. While generally interested in metallurgy, he devoted himself more particularly to the production and properties of iron and steel. He applied the phase rule of Willard Gibbs for which he devised simple proofs, and it is said that without Le Chatelier's principle of mobile equilibrium the phase rule and phase law diagrams might have waited long for their practical applications. While working in the field of metallurgy he devised a metallurographic microscope with which he could study and photograph crystals in alloys. This device divulged

the formation of compounds between iron and carbon, and proved the value of heat treatment in steel. His dilatometer enabled him to measure the expansion rate of metals. Le Chatelier experienced difficulty in the


EVOLUTION DU MICROSCOPE H. LE CHATELIER
Fig. 1 et 2. — Modèle du microscope créé en 1901.
Fig. 1. — Schéma de l'appareil.
Fig. 2. — Vue d'ensemble de l'appareil.
Fig. 3. — Microscope perfectionné. Installation de métallographie montée sur banc en fonte de 2 mètres de longueur. Type original à axe optique surbaissé.

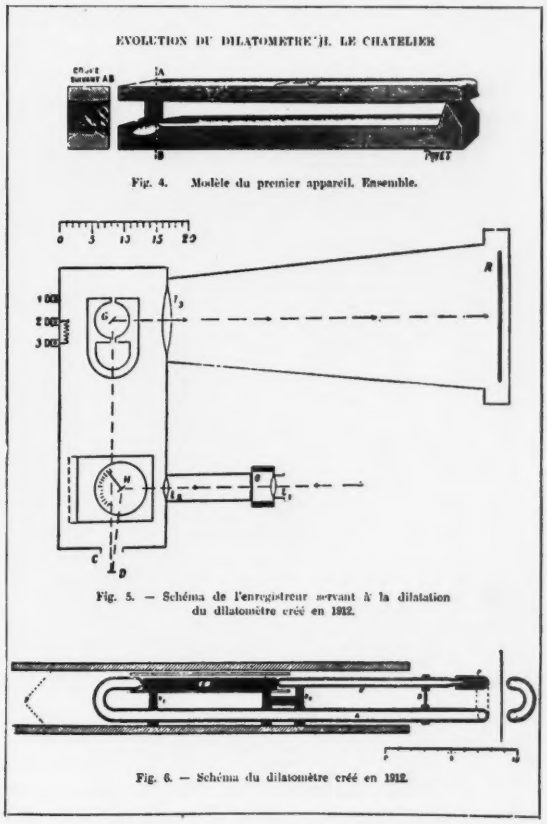
METALLURGICAL MICROSCOPE OF HENRY LE CHATELIER

measuring of the higher temperatures in his studies. Instruments were in existence which would measure up to 500°C., but beyond that results were inaccurate. He adopted the platinum platinum-rhodium thermocouple, for gas thermometers were unreliable.

In the field of ceramics Le Chatelier was interested in mortars and cements, clay, silica, and the silicates, glass. He determined the coefficient of expansion and electrical conductivity of some of these materials.

Henry Le Chatelier published over five hundred journal articles and books.* They not only included chemistry and ceramics, but numerous biographies, and, toward the end of his life, articles on social welfare.

Le Chatelier's books included a volume on the measurement of high temperatures which appeared in 1900 under the joint authorship of O. Boudouard. This volume underwent numerous revisions and translations, and is known in the United States under the title, "The Measurement of High Temperatures," by Burgess and Le Chatelier. In 1903 a volume appeared on "Hydraulic Materials." This dealt with lime, mortars, and cement. Again, the volume was revised and translated. In 1908 he published his "Lessons on Carbon." This volume had its beginning in his early lectures on the subject. 1912 brought his "Introduction to the Study of Metallurgy" which included industrial heating. In 1914 his volume on "Silica and the Silicates" appeared, and in 1925 his book on "Science and


EVOLUTION DU DILATOMETRE H. LE CHATELIER
Fig. 4. Modèle du premier appareil. Ensemble.
Fig. 5. — Schéma de l'enregistreur servant à la dilatation du dilatomètre créé en 1912.
Fig. 6. — Schéma du dilatomètre créé en 1912.

HENRY LE CHATELIER'S DILATOMETER

Industry." In the last named volume he particularly stressed the Taylor system of organized management and production which originated in England and which he greatly admired.

In his books and journal articles Le Chatelier's exact scientific trend of mind is in constant evidence. He provides illustrations, but sparingly, and never superfluously. His translators were more generous in this regard than the author himself.

Le Chatelier was a great national figure. His linking of science with industry and especially with national defense was important to France, for not only the nation but the Academy of Sciences had neglected this. His frequent appeals to the French Academy of Sciences, in which he referred to the utilization of science in industry and national affairs in Germany, Great

* "Henry Le Chatelier: His Publications," *Ceram. Abs.*, **16**, 316–22 (Oct., 1937).

Britain, and the United States finally won national support for research, and his favorable reference to our own nation undoubtedly prompted Woodrow Wilson to consult him in an advisory capacity when our National Research Council was established in 1916.

The reward of Le Chatelier's appeal to the National Academy of Sciences and the French nation came through his numerous appointments. He was on the French Commission on Explosives in 1902, the National Science Bureau in 1913, the Commission on Weights and Measures from 1913 to 1917, and the Commission

HENRY LE CHATELIER (ENLARGEMENT FROM 16-MM. MOTION PICTURE TAKEN BY A. S.), APRIL, 1934

for the Standardization of Metallic Products. Upon him was placed the responsibility for specifying standards, for materials of construction other than wood, and his committee finally determined the standards for all products. In 1919 France made him a member of the Commission on Inventions, and in 1922 he was placed on the Committee for the Control of the French Monetary Circulation. Le Chatelier represented France at numerous international meetings.

Henry Le Chatelier was the recipient of many honors. These included the Jerome Ponti Prize of the French Academy of Sciences (1892), and the Lacaze Prize (1895). In 1907 he was made a member of the French Academy of Sciences. It may seem strange that the Academy should have waited so long, but one has only to think of the case of Louis Pasteur to realize that election to this body requires time. He had been a Chevalier of the Legion of Honor of France since 1886. In 1908 he became an officer, in 1919 a Commander, and in 1927 Grand Officer. In 1906 he was made a knight of the Order of St. Anne of Russia, and in 1928 a Chevalier of the Order of the New Republic of Poland.

His applications of science to industry brought him recognition which scientists rarely receive. Thus, in 1900 he received the Grand Prize of the Paris Exposition; in 1908 the Medal of Honor of the Society of Mineral Industry of France; in 1928, the Gold Medal of the Commission on Bridges and Highways of France. In 1904 he received the Grand Prize of the St. Louis Exposition (U. S. A.); in 1905 the Diploma of Honor of the International Exposition in Liege, Belgium; in 1906 the Grand Prize of the International Exposition in Milan, Italy. During 1910 he received the Grand Prize of the International Exposition in Brussels, Belgium; the Grand Prize of the Franco-British Exposition; and the Bessemer Gold Medal of the Iron and Steel Institute of London. In 1911 the International Exposition of Industries and Manufactures of Turin, Italy, awarded him the Grand Prize. In 1916 he received the Davy Medal of the Royal Society of London. In 1932 he was awarded the medal of the Association of Engineers of Liege, Belgium. Henry Le Chatelier was not only a member and officer in many national and foreign societies, but was made an honorary member of innumerable organizations.

Le Chatelier's honorary degrees included that of Doctor of Engineering from Aix la Chapelle, Germany (1910); Doctor of Science from the University of Manchester, England (1920); Doctor of Technical Science from the Polytechnique Institute of Copenhagen, Denmark (1921); Doctor of Science, University of Louvain, Belgium (1927); Doctor of Science, University of Madrid, Spain (1934).

It would hardly seem right to present this article without saying something of Le Chatelier's family life. On May 29, 1876, he married Genevieve Nicolas, the daughter of a former chum of his father at the École Polytechnique. There were seven children by this marriage, three sons and four daughters. The influence which Henry Le Chatelier enjoyed through his grandfather, his father, and mother, and their families is repeated through his influence and that of Mme. Le Chatelier on their children and grandchildren. The oldest son, Charles, became a mining engineer. The oldest daughter married an engineer. The next daughter also married an engineer and after her marriage coöperated with her father in establishing the *Revue de métallurgie*. The third daughter married an agricultural engineer. The son, Louis, is an engineer. The fourth daughter married an engineer, and the youngest child, a son François, is a mining engineer. It is to this son that the writer is particularly obligated for much of the valuable information contained in the present article.

In June, 1936, Professor and Mme. Le Chatelier celebrated their sixtieth wedding anniversary surrounded by their children, thirty-four grandchildren, and six great-grandchildren. Le Chatelier devoted all of his spare time to his family. The tall, slender, serious, but pleasant, father played with the children and would take them on numerous excursions. He interested himself in their studies and in the studies of his grandchildren. It is said that in the spring of 1936 he went to Miribel-les-échelles with his grandchildren to give them a review in chemistry and physics, and that on

the eve of his death, disregarding his fatigue, he dictated to one of his children advice concerning the study of descriptive geometry to help a grandchild who was experiencing difficulty with the subject.

We must pay tribute to Mme. Le Chatelier. Her self-abnegation as the wife of a professor with a limited income, and her devotion to the education of her children to lighten the burdens of her husband as much as possible proved an important factor in helping to establish his brilliant career.

Le Chatelier traveled extensively in the interests of his studies and through invitation of foreign societies; also during his vacations, when Mme. Le Chatelier invariably accompanied him.

Finally, like most scientists who reach a ripe old age, he indulged in philosophy. On January 22, 1922, the French Academy of Sciences celebrated the fiftieth anniversary of Le Chatelier's graduation from the École Polytechnique and presented him with a bronze medal. Copies of this medal by an eminent sculptor had been distributed in return for subscriptions which resulted in a fund of 100,000 francs. This fund was presented to the Academy of Sciences in Le Chatelier's honor and utilized for researches under his direction. There were many addresses in which he was given high praise and commendation. When his friends and associates had finished Le Chatelier thanked them and closed by stressing some of his own ideals. He emphasized the necessity for clear thinking verified by exact experimentation, and illustrated the importance of this procedure by citing the failures of a number of eminent men whose carelessness resulted in embarrassment following their published accounts of faulty researches. He told how his pleasure in life had come through studying the laws of the universe, observing their application and discovering new consequences. He warned against the tendency to invalidate or question natural laws and said that one should aim to confirm those laws which predecessors had disclosed. He felt that this attitude was an advantage which led to his own supplementary contributions and which accounted for that measure of his success which the Academy was celebrating. He could not destroy the edifices of the past, for he considered science "a collection of contributions made by many workers, which might be supplemented or modified by duly authenticated new discoveries." He stressed the importance of discipline which his parents had imposed upon him and which was practiced at the École Polytechnique while he was a student. He deplored the decreasing seriousness of study and increasing tendency toward pleasure and even license in modern colleges and universities. He likened the irresponsible student to a bold individual who dodges vehicles in crossing a street and risks being crushed, to say nothing of the fact that he seriously ties up traffic. To the young chemist he recommended modesty with a reluctance to overthrow the findings of the past until he has positive proof. "One makes discoveries if he can and not merely through the wish to make them. The sensational is detestable." Of himself Le Chatelier said, "... throughout my scientific career I strove without any desire for the sensational, contenting myself each day with the conscientious pursuit of the task of the day. In the end I was amply rewarded."

Le Chatelier was a lover of liberty and cherished the privileges which men enjoyed in the French Republic. He differentiated between discipline and liberty. To him discipline meant the voluntary respect of the law, whether natural or social. He characterized civilized man through recognition and respect of the law. To him liberty consisted not in the breaking of laws, but, on the contrary, in the prevention of law violation. Liberty refuses to tolerate injustice and should modify laws instead of revolting against them.

Le Chatelier placed integrity above everything. At one time after he had received an honor, a statesman approached him for a favor to a particular political faction. Le Chatelier replied, "I have never sought an honor, and I, therefore, assume that when it was conferred it was mine without obligation." He might have enjoyed many favors and promotions had it not been for this ideal. In fact, he lost his chair in the École Polytechnique through his conscientious adherence to his principles.

HENRY LE CHATELIER AND MME. LE CHATELIER. (ENLARGED FROM 16-MM. MOTION PICTURE TAKEN BY A. S.) APRIL, 1934

After his retirement and during the last years of his life, he became interested in numerous problems of a general nature. He campaigned for the return of the classical studies to college and university curricula, stressing the importance of literature and Latin as a part of a general education. As already intimated, he advocated scientific management according to the Taylor System, and others, for increasing the efficiency of workmen in French factories. He advocated political economy, recommending a more liberal status for the workman and a greater restraint on political expenditures. Shortly before his death, as President of the inaugural International Congress of Mines and Metallurgy and of Applied Geology, at which delegates from forty nations were present, Le Chatelier took occasion

to indicate that much attention was being given to the development of industrial technic which was based on the collaboration of science and industry. He admitted that at one time he had supported this policy and that it was still desirable, but lamented the fact that not enough attention was being paid to social progress. Wishing to leave this thought as an indelible impression, he prepared an article entitled "Morals and Human Affairs." So anxious was he that the manuscript should be exactly right, that he corrected it on his death bed, and insisted repeatedly that it be

HENRY LE CHATELIER AND MME. LE CHATELIER WITH CHILDREN, GRANDCHILDREN, AND GREAT GRANDCHILDREN CELEBRATING DIAMOND WEDDING ANNIVERSARY, JUNE, 1936

sent to a journal where the ideals expressed would make a sympathetic appeal, namely, the *Bulletin of the Social Union of Catholic Engineers of France*. It appeared in this *Bulletin* as a posthumous article in December, 1936.

After 1935 Le Chatelier suffered occasionally from angina pectoris. Several days before his death a particularly violent attack affected his heart, and he succumbed. His death was a peaceful one, on September 17, 1936, at his country estate, Miribel-les-échelles (Isère), France, in his eighty-sixth year. The writer pays tribute to Henry Le Chatelier, one of the world's greatest scientists, in a poem which was previously prepared for a memorial article.

"Father studied on Earth's minerals,
Father's father burnt its lime,
Mother's forebears mapped world nations,
She herself was soul sublime.

Thus, the son, one born of Genius,
Nurtured by the mother's care,
Guided by the father's wisdom
Must find interest everywhere.

And he did, in Natural Science,
Striving morning, noon and night,
Wrest from Earth some of her secrets,
Set them forth, as well he might.

First the gross, the coarser findings,
Then with microscope, the small,
Next the laws, their explanation
Gave this Savant, slim and tall.

Always striving, earnest, modest,
More to learn and more to give.
Discipline, his life, his motto,
Showing others how to live,

Not for pleasure, not for glamour
But to serve both Man and State.
In this service helped a woman,
That self-sacrificing mate

Who with patience him encouraged,
Bore him sons and daughters rare.
These love art and science also,
Further lay Earth's secrets bare.

Nations far and wide our Scholar
Honored in their Guilds, and then
Made him of their Groups a member;
Always happy, where and when

He would visit, in his travels,
Their great scholars, more to learn;
Learn, but giving more than taking,
Adding to Minerva's urn.

Flames he measured, as to hotness,
Even solar heat, so high.
Glasses made he in the furnace,
Products pleasing to the eye.

But his sunset saw the smoulder
In his fellow worker's breast,
Which portraying surface under
Showed a feeling of unrest,

Showed that some had blessings many,
Others few. These torn with strife
Often suffered untold tortures,
Trudging through the walk of Life.

Thus, on death-bed, leaving Science,
He espoused the Public Weal,
Pleading strong the Cause of Justice,
Signing with his last Earth-Seal.

May his message bear fruition,
Lift from Life its shaded hood,
Make men see that Life's worth living,
Holding hope, and boding good.

Gone our Savant. Yes, in body;
Not in mind or soul, for they
Will abide with us forever.
They'll live Aeons, no mere days."

Illustrations which accompany this article are presented through the courtesy of the *Revue de Métallurgie*, Paris, which issued a special memorial number in January, 1937. The other photographs are enlargements from motion pictures which the writer had the privilege of taking in Professor Le Chatelier's residence in Paris during April of 1934.

The RÔLE *of* ANALYTICAL CHEMISTRY *in* INDUSTRIAL RESEARCH

*III. THE TRAINING OF ANALYSTS**

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QUIETLY, without fanfare, the science of analysis is emerging from a long bloodless revolution. This seems to be somewhat more fully realized by supervisors of analytical laboratories in industry—the employers of analysts—than by professors of analytical chemistry—the trainers of analysts. This article is written in the belief that if the trainers understand better the viewpoint of the employers, both will benefit; the former from the consciousness that they are doing a more useful job, and the latter from the availability of realistically oriented personnel.

The bloodless character of the analytical revolution derives from the absence of the spectacular in the development of the science: it has grown not by jumps, but by slow accretion. When we think of the history of analysis there comes to mind a series of names, Boyle, Lavoisier, Berzelius, Stas, Fresenius, T. W. Richards, Pregl, Emich, and many others. Organic chemistry had its Kékulé and its Wöhler; physical chemistry its Arrhenius-van't Hoff-Ostwald triumvirate; subatomic chemistry its Curies—all towering landmarks that fix absolute beginnings or right-angle turns. The history of analytical chemistry has no comparable landmarks. Robert Boyle coined the name, but few would contend that he invented the science. As to the others, who will say which made the more important contribution to analysis, Lavoisier or Berzelius, Pregl or Emich?

In the days before the era of physical chemistry, say, before 1880, analysis consisted in the main of elaborate, ingenious, and often extremely tedious processes for breaking down complex substances into recognizable compounds of known composition. The reactions used were largely those discovered by the synthesist, and thus not necessarily suited to analysis; little deliberate search for suitable reactions was made. The laboratory apparatus was a hand-me-down from the synthesist, as was the technic of experimentation. For the measurement of quantity one was limited to simple, direct gravimetric or volumetric methods. It is fair to say that in this period analysis was the stepchild of chemistry.

Physical chemistry brought about the first stage of the analytical revolution. The ionization concept, leading to such other concepts as the solubility product and the theory of indicators, clarified for the analyst his classical reactions, making his results more precisely predictable, and led him to modify his procedures in the direction of efficiency. Electrochemistry has contributed not only new concepts, such as that of pH, but many entirely new technics, not only of carrying out analyses, but of the measurement of the final products. One may mention at random potentiometric titration, "internal" electroanalysis, the dropping mercury cathode technic (the "Polarograph"), and conductimetric titration. The understanding of the colloidal state has enabled us to use it where desirable, as, for example, in the separation of tin under certain conditions by co-precipitation with colloidal iron hydroxide (*4*), and to avoid it where it is a hindrance, as in the precipitation of metallic sulfides by thioacetic acid instead of by hydrogen sulfide. The colloidal state is also involved in colorimetry, turbidimetry, and nephelometry.

Next to physical chemistry, the development of microanalysis is perhaps the most significant thing that has happened to chemical analysis in the present century. It is important not only because it permits us to do things hitherto impossible but because microanalysis gives—or *should* give—to the analyst an altogether new viewpoint. As the writer sees it, the central idea of classical microanalysis is extremely simple: if the apparatus and the technics and the reactions and the instruments of observation of other branches of chemistry prove inadequate for analysis—don't say the job can't be done, but invent or adapt new apparatus and technics and reactions and instruments.

That it has taken us a century or more to realize that we are not forbidden by any law to use smaller scale apparatus than our synthesist colleague, is no credit to us. To continue, hidebound by classicism, to ignore or to sense only dimly our emancipation, is even less creditable.

During the last several decades there has been another force, an external one, beating against the science of analysis and compelling its rejuvenation. As industry has advanced, mechanisms have become increasingly delicate and complex, and more refined correlations between

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* For the other articles in this series, see literature references (*1*) and (*2*). Reference (*3*) may also be of interest.

† Member, Board of Advisory Editors, *Industrial and Engineering Chemistry, Analytical Edition.*

chemical composition and mechanical or electrical performance have been correspondingly demanded. This has necessitated methods of analysis at once more accurate and more rapid, and in many cases departures of revolutionary magnitude from classical lines.

At the same time, the development of X-ray analysis, and of subatomic and nuclear chemical physics, has made us acutely conscious of the fundamental principle of natural philosophy that the properties of matter are determined by intraätomic, intramolecular, intercrystalline, and interphase attractions and repulsions. We must, therefore, measure, in so far as we can, not average forces for the mass, but forces at specific locations.

These changes in the objectives of analysis have put a new burden on the analyst. He has had to become a detective. In all industries, but particularly in those like the electrical, in which the main technological process is non-chemical, there arise difficulties in the functioning of materials that defy resolution by the non-chemical engineer. The engineer logically turns, then, to chemistry for help. His first impulse usually is to ask to have an "analysis" made. That may indeed be what he needs, in which case any competent analyst trained and oriented along classical lines can solve the problem. But often what he needs is an analysis by a chemical *mind* of his *problem*, rather than an analysis by a chemist's *hands* of his *material*.

The chemist competent to serve in this capacity must be much more than a mere analyst. He must first of all have the mental outlook of the research consultant; and this involves considerable knowledge of the non-chemical technology of the particular industry, and familiarity with materials gained through experience, as well as a thorough grasp of all the pertinent branches of chemistry. His survey of the problem may lead him to the conclusion that what the engineer needs is the help of, say, the organic specialist in the chemical group, and he so advises; or he may decide that chemistry is not involved. In either of these cases his services as an analyst are not required.

But many cases arise where something chemical must obviously be done, and yet the problem seems to fall into no one of the so-called branches of chemistry. Then he sets about making what we have to term, for want of a better designation, a chemical analysis. He becomes involved in what Lundell calls, in his admirable paper of that title (*5*), " the chemical analysis of things as they are." For consistent success in such problems he must not only have a thorough knowledge of chemistry as a whole and of other branches of physical science, but he must be able to use to a considerable extent the methods of attack (as well as some of the apparatus) of the criminologist and the medical diagnostician.

There is a knack that theoretical training does not give of selecting the most likely of a number of leads. Subconscious judgment, probably based on observations filed away in the subconscious mind, a sense of relative importance, of detecting the true or false ring of a proposed explanation—all these are necessary. A few principles known and effectively applied will often accomplish more than volumes of theory, which in the absence of discrimination born of contact with practical problems may lead into blind channels.

Thus the type of work such a chemist does is no more adequately described by "chemical analysis" than is the work of the clinical pathologist by "bacteriology." We propose that the adjective "chemical" be dropped and he be called simply an analyst, or possibly a "materials analyst," for his work, in the modern industrial laboratory, deals with operations that diverge increasingly from the strictly chemical. Had not the word "diagnostics" such a definite medical connotation, it would be even preferable to "analysis," since it is not uncommon for synthetic methods to be used by the "analyst."

Probably the most important problem before the modern industrial analyst, after deciding upon a plan of action, is to isolate from the complex material before him a sample suitable for straightforward analytical attack. Too great emphasis cannot be placed upon this point. Analytical chemists fresh out of school seldom have any consciousness of the fact that the preparation of the sample for analysis is often the major part of the job, because their college work deals almost exclusively with the analysis of pure substances. In this connection, a paragraph from Lundell's article (*5*), deserves quoting.

"Methods of the type described are about as helpful as the method for catching a bird which the old folks used to recommend to children—namely, to sprinkle salt on its tail. To do that, one must obviously have the bird in hand, and in that case there is no need for the salt. So it is with much of the advice that the analyst receives. Minute directions are given for the salting away of the quarry after it has been separated from its fellows. In this connection, it is interesting to note that when the analyst does happen to encounter a 'pure' compound his chief concern is with the impurities rather than the major constituent. In other words, the absolute purity of a pure compound is established by determinations of its impurities."

Another question is how far to go with the analysis. Maximum precision and accuracy is the aim of the conventional chemical analyst; the aim of the practical materials analyst is maximum *significance*. The extent of an analysis depends upon the uses to which the results are to be put. Ultimate resolution of the material is often unnecessary and frequently undesirable. For example, an elementary analysis of a mixture of fatty acids is useless in arriving at the formulation of the mixture. Much more ingenuity and less conventionalized technic are required to separate and identify the individual acids. Again, steel contains non-metallic impurities which are determinable with speed and accuracy by an analyst of little training. For control purposes, this leaves nothing to be desired. But for the research physicist working, for example, on a problem in magnetics, the important thing may be how these impurities are combined. Hence, the much more difficult problem arises of isolating and identifying compounds.

The materials analyst must have versatility and adaptability. He must recognize those cases where a

phenomenon can only be understood by studying it in relation to its surroundings, and those where the sample submitted is not the sample that should have been taken. He must therefore be prepared to go into the field and either perform his analysis on the material *in situ* (with special portable apparatus which he has built for the purpose) or else *select* the proper sample to take back to the laboratory. The physician must be able to diagnose his patient's ailment as successfully—if not as easily—when the patient is bedridden and cannot be moved as under the ideal conditions of a hospital; so it is, analogously, with the materials diagnostician.

The industrial analyst of today must spend a good part of his time developing new methods, or adapting old ones to new materials. Such work is research, frequently research of a high order; for, as Willard (*6*) has aptly said, "It takes brains to devise the simplest test, but carrying it out may be largely mechanical." The analyst who works under the assumption that any departure from the standard textbooks is heresy, will not succeed in industry. So, also, with the man who is what we might call "pigeonhole-bound"—who thinks analysis is a self-contained branch of science bearing no relation to, say, organic or physical chemistry or to physics. No intelligent graduate really believes that in his conscious mind; but, in the writer's experience, far too many emerge from college with their chemical subconscious patterned by that fallacy.

There is a curious tendency to hero worship in science which may at times be paralyzing. Because one was a student of Pregl, for example, or even a student of a student of Pregl, is no excuse for assuming, however tacitly, that the alpha and omega of organic microanalysis are comprised in his writings. To put the whole argument in a sentence, the analyst must get over the habit of asking himself, "Can this job be done by analytical chemistry (or microanalysis, or colorimetry)?" and substitute the thought, "This job has got to be done, even though I have to use medieval history!" Nobody cares about the names of the streets through which a messenger passes, so long as he gets quickly to his destination.

We employers of analysts have neither the desire nor the ability to tell the teachers either how or what to teach. But it is possibly within our province to indicate, as the writer has done according to his lights, some of the shortcomings of the product. In addition to those already mentioned, several others will be cited.

The analyst should come out of college with a much more extensive knowledge of materials and industrial processes than he usually does. Engineering chemistry students receive such training, but their courses in analysis are inadequate. A combination of good analytical training with chemical engineering is perhaps the best preparation.

Let the student be guided gently, while still in college, from the shining realm of ideality, where all the laws are obeyed perfectly and there is a paragraph in the textbook for every contingency, into the rather drab world of things as they are, where matters are rather different. Give him some *practical* problems (there is no dearth of them) that involve analysis in their final phases but do not consist merely of analysis.

Teach him how to blow glass—not certainly to be an expert, but at least to be able to join two tubes end to end acceptably and without ruining both his disposition and a pound or so of tubing. Show him how to design and construct apparatus of moderate complexity. Give him some idea of how industrial analytical laboratories are organized. Orient him into reality.

Now, finally, the writer was relieved to come upon evidence that he is not alone in his grumblings, that similar complaints are made even overseas. At the Manchester meeting of the British Society of Chemical Industry on April 2, 1937, a symposium was held on "The Chemist in Industry." The following is quoted from the summary (*7*) of that symposium.

"(*a*) For certain classes of work, graduate chemists do not appear to be sufficiently trained in manipulative technique, possibly through the attempt to put too much in the curriculum.

"(*b*) There has been too little contact between industry and the teaching institutions generally."

The writer cannot agree that the difficulty lies in a too-full curriculum. Possibly it is that curricula looking toward the production of industrial analysts are not full enough of the right things. Perhaps we are expecting too much of the universities. Perhaps it is not humanly possible in four years to give the indispensable training in fundamentals and in addition the more practical training that has been indicated as needed. In most controversies (if this, being thus far one-sided, can be so described) the ultimate answer is compromise. Probably that is the answer here.

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A SURVEY *of* INFRA-RED SPECTROSCOPY*

Part I. The Early History and the Methods of Infra-red Spectroscopy

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THE advances of experimental physics during the past few years, particularly the discoveries of the Raman effect and the hydrogen isotope of mass 2, together with the vast improvements in theoretical interpretation of polyatomic molecules, have furnished the impetus for corresponding developments in the field of infra-red spectroscopy. Within the last twenty years, in fact, experimental infra-red has advanced from the status of a series of near experiments to a definite place as an important branch of spectroscopy and a most powerful tool for the investigation of the structure of molecules.

This paper is intended both for the general reader and for the student who has only recently become interested in the infra-red. Reference cannot be made here to every investigation that has a bearing upon the subject; only those are mentioned that seem best to illustrate the points in question. For more complete bibliographies one should refer to the recent treatises and articles in this field (*1*).

HISTORICAL REVIEW

In 1800 Wilhelm Herschel performed experiments that aided greatly in clarifying and advancing the study of spectra, and that at the same time marked the discovery of the infra-red. He placed the bulb of a sensitive thermometer in the various regions of a solar spectrum and observed the rise in temperature of this thermometer with respect to a similar one that was kept out of the spectrum. His results indicated a rise of 2° in the violet, 3.5° in the green, and 7° in the red, thus showing that radiant energy was present in all parts of the visible spectrum. He next proceeded to estimate the relative brightnesses of the various parts of the spectrum and found a decided maximum in the green and yellow. The fact that the distribution curves for the heat and light did not agree disturbed him, and led him to search for the maximum of the heat curve. In a second publication Herschel announced that this maximum was out beyond the red end of the spectrum. With a visible spectrum 4 inches long, he found a maximum of 9° rise in temperature 1.5 inches beyond the red end and no appreciable rise at all beyond the violet end** (Figure 1).

Immediately there followed a long series of investigations to determine whether these invisible infra-red, or "heat," rays and visible light were the same, or whether they represented different phenomena. It was easily discovered that both followed exactly the same laws of refraction and reflection. Herschel demonstrated that although the infra-red rays were refracted

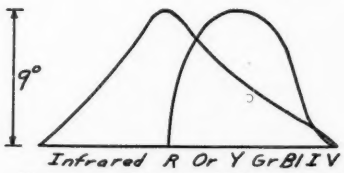

FIGURE 1.—HERSCHEL'S COMPARISON OF THE DISTRIBUTION OF LIGHT AND HEAT IN THE SUN'S SPECTRUM. THE VERTICAL SCALE OF THE LATTER CURVE IS CHOSEN TO MAKE THE TWO MAXIMUMS THE SAME HEIGHT. A GLASS PRISM WAS USED

according to Snell's law, they were refracted much less by a given lens than was visible light. The transmissions of various substances for infra-red and visible radiation were then studied and found to be greatly different, some materials being opaque to light and at the same time transparent to the infra-red, and vice versa. Because of this, and because of their different

* Part I of this material has appeared previously in *The American Physics Teacher*, but the whole article is printed here for the sake of completeness. Part II, "The Origin, Appearance, and Interpretation of Infra-red Spectra," will appear in the January issue of the JOURNAL OF CHEMICAL EDUCATION.

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** In 1801, J. W. RITTER (*Gilbert's Ann.*, **7**, 527 (1801); **12**, 409 (1803)), found that the photographic action of light on silver chloride extended beyond the violet end of the spectrum. He verified the existence of the infra-red rays reported by Herschel, and noted that they greatly retarded the photochemical action of light.

distribution curves, Herschel remained firmly convinced that the invisible rays and light were fundamentally different. Later studies of the dependence of the emission upon the temperature of the source and studies of the selective absorption of various materials made it clear that these visible and invisible rays were identical in character.

Throughout the next half-century the history of spectroscopy is intimately associated with the names of Young, Wollaston, Fraunhofer, Brewster, J. F. W. Herschel, the son of the discoverer of the infra-red,

FIGURE 2.—J. F. W. HERSCHEL'S PICTURE OF THE SUN'S SPECTRUM, PRODUCED BY THE DIFFERENTIAL EVAPORATION OF ALCOHOL FROM A SOOT LAYER

Helmholtz, Talbot, and Kirchhoff. During this period many a heated argument was held regarding the discovery and interpretation of the Fraunhofer lines, and the possibility of identifying a substance by means of the spectrum which it emitted. In passing, it is interesting to note that the understanding of this latter possibility was delayed some thirty to forty years by the fact that sodium is found in minute quantities almost everywhere—the yellow D lines were observed in every flame and in every other source of light. Had it not been for this puzzling fact, Herschel and not Kirchhoff might today be looked upon as the real founder of spectroscopy.

Introduction of the Thermopile

The next chapter in this history must certainly begin with mention of the discovery of thermoelectricity by Seebeck in 1823 and its subsequent use by Becquerel in temperature measurements. Nobili soon afterward constructed a thermopile and used it successfully with his sensitive astatic galvanometer to measure very small differences of temperature, but it was in the hands of Melloni, later on, that this instrument was developed to its fullest value. Using thin wires of bismuth and antimony, he constructed a thermopile of many junctions and achieved with it a sensitivity over ten times that of his best thermometer. For a period of twenty-two years he was busy with this new instrument and carried out many infra-red investigations. He showed definitely that the position of the energy-maximum in the sun's spectrum was determined by the particular prism used, and explained this fact correctly as being due to the selective absorption of the prism material. He was able also to show that the infra-red rays were not homogeneous but consisted of many different rays, analogous to the manner in which white light had been shown to be made up of various colors. He spoke of the "colors" of the infra-red rays and after finding that different bodies behaved toward the transmission of these rays just as transparent colored and colorless materials behaved toward visible light, spoke of the "heat color" of a material. Rocksalt and fluorite he found to be "colorless," whereas soot was opaque to rays of every color. This great similarity between infra-red and visible radiation convinced him that they were the same phenomenon.

Fizeau and Foucault demonstrated the interference of two beams of infra-red radiation by measuring with a very sensitive thermometer the fluctuations of temperature in the interference bands. They then studied the infra-red part of the sun's spectrum and located several strong Fraunhofer lines. There soon followed a large number of researches on the transmission of many substances and also various attempts to determine the absolute wave-lengths of the infra-red radiation. Since nearly all of these studies were made with the emitted radiation undispersed, they are of little value.

In 1840, J. F. W. Herschel announced in a paper read before the Royal Society that he had succeeded both in making visible the infra-red rays discovered by his father and in proving that they are not continuous but consist of several groups of rays. His ingenious method was a type of photography which has formed the basis for some very successful experiments recently made by Czerny, and which will be discussed later. Herschel allowed the sun's spectrum to fall upon a piece of paper which he had previously coated with soot and dampened with alcohol. The alcohol evaporated fastest where the radiant energy was concentrated and absorbed by the soot, thus leaving dry spots (Figure 2). In agreement with the results previously published by his father a long, dry band was obtained extending from the violet throughout the visible spectrum and out beyond the red. In fact, as Figure 2 shows, the most intense heating occurred beyond the red end. He pointed out that the regions in between the dry spots, regions in which very little heat was present, represented Fraunhofer lines and were caused by absorption of the radiation by the atmosphere of either the sun or the earth. Although several other investigators failed in their attempts to repeat this important experiment, Czerny's recent experiment has proved the value of Herschel's work.

Dispersion Measurements

The third important chapter in this history begins with the work of Langley. In 1849 Svanberg constructed the very sensitive instrument known as the bolometer. He made no use of this instrument, however, and in 1881 Langley rediscovered it. In a series of papers Langley reported the results of careful measurements of the spectra of the sun and the moon, and of the emissions of many substances when heated to various temperatures.

The bolometer, which is in reality merely a very delicate resistance thermometer, supplied infra-red investi-

gators with a detecting device of sensitivity many times that of any instrument previously used. Measurements could be made even when the emitted radiation had been considerably dispersed. There was accordingly an immediate need for accurate measurements of the dispersion of those substances that had been found suitable for prisms and these were furnished by Langley, Rubens, Trowbridge, Paschen, and others, for quartz, fluorite, sodium chloride, and potassium chloride. Their work was of such an excellent nature that the values are still in use today. Many years were required for the completion of these measurements which were finally extended in the case of KCl to a wave-length of 22μ (22 x 10^{-4} cm.).

Early Applications

The bolometer, which had been used so successfully, was soon forgotten and a more sensitive form of the thermopile brought back into use by Rubens and others. A combination of a thermocouple and a moving coil galvanometer—the microradiometer—was later introduced by C. V. Boys; this instrument is in use today and rivals the most sensitive of our receiving devices. The radiometer, a form of the old Crookes "light mill," was also introduced by Rubens and proved itself to be of great value as an extremely sensitive heat-detecting device.

Equipped with these sensitive instruments, many workers now entered the field, and a great number of investigations were carried out, principally in two directions: the extension of the infra-red to still longer wave-lengths; and the study of the absorption of infra-red radiation by various solids, liquids, and gases.

Undoubtedly, the most successful worker in extending the infra-red to longer wave-lengths was Rubens (*2*). In 1897 he carried out his first experiments on selective reflection. From the dispersion measurements which had previously been made one could predict that NaCl and KCl should possess a region of selective reflection somewhere far out in the infra-red. Rubens located such regions at 52 and 61μ. For these wave-lengths NaCl and KCl have a reflectivity of approximately eighty per cent., whereas for other wave-lengths the percentages are very low. Rubens called these reflected beams of energy *reststrahlen*, and located the reststrahlen for some thirty crystals. He developed this method of monochromatizing the infra-red into a powerful tool with which he and his co-workers were able to work as far out as 150μ. Rubens and Wood (*3*) made use of the difference in refractive indices of a quartz lens for visible light and infra-red and were able to isolate from a Welsbach mantle radiation of wave-length 110μ. Later, Rubens and von Baeyer (*4*) showed that the infra-red radiation emitted by a quartz mercury lamp consisted of two strong maxima at 218 and 343μ. Nichols and Tear (*5*) filtered these radiations through four layers of black paper and 8 mm. of fused quartz and thus detected energy as far out as 420μ. These long waves bridged the gap that had existed between the infra-red and the Hertzian waves, the shortest of which were 100μ in length and were produced in 1924 by Glagolewa-Arkadiewa (*6*).

The pioneers along the other line of investigation, namely, the study of the absorption of various substances, were Julius, Ångström, Paschen, and Coblentz. Julius (*7*) found that all organic compounds that contained a CH_2, CH_3, etc., group had similar spectra, a fact which today plays a basic rôle in our infra-red analysis of molecular structure. Paschen's (*8*) extremely accurate work on the dispersion of fluorite has already been mentioned. By studying the emission of solid bodies at various temperatures, he successfully determined the function in Kirchhoff's law and obtained for it the same expression as that obtained theoretically by W. Wien. Coblentz published in 1905

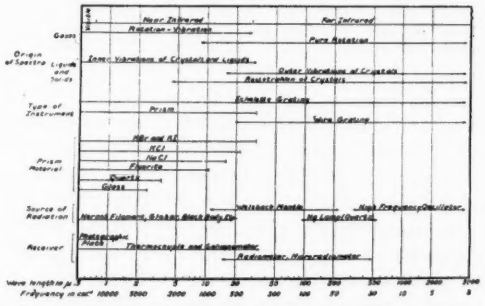

FIGURE 3.—THE INFRA-RED SPECTRUM. MANY OF THE REGIONS MUST BE REGARDED AS ONLY ROUGHLY DEFINED BY THE MARKINGS IN THIS DIAGRAM

the results of an extended investigation, in which he measured the transmission of a large number of compounds from 1 to 16μ. These results, together with similar measurements of the emission and the reflection of many substances, were published in three volumes by the Carnegie Institute (*9*) and form today the foundation of every beginner's knowledge of infra-red spectra.

With a mere mention of the work of Eva von Bahr who showed that an infra-red band consisted of many fine lines, of Pfund and Schaefer who showed independently that all compounds possessing a radical such as the SO_4, CO_3, or NO_3 groups had similar spectra, and the work of Lummer and Pringsheim whose exact measurements of the emission of black bodies paved the way for Planck's radiation formula and the quantum theory, we may consider that the historical development of the infra-red has been sufficiently emphasized.*

METHODS OF STUDYING INFRA-RED SPECTRA

Sources

Very early in the history of the infra-red, the experimental laws now commonly referred to as Kirchhoff's

* For a most interesting and complete account of the history of spectroscopy the reader is referred to Kayser's *Handbuch der Spectroscopie* (1900), Chap. 1.

law, Wien's displacement law, and the Stefan-Boltzmann law were discovered, and it became evident that the best source for use in the infra-red was a "black body". Various attempts were made by Wien, Lummer, Pringsheim, Kurlbaum, and others to construct such sources. These were usually in the form of electrically heated ovens, one end of which had a window out of which the radiation emerged. They were practically perfect black bodies. In practice today, however, one generally uses a small strip of hot platinum or a rod of carborundum known as a "glo-bar." These sources, while not really "black," may be operated at about 2000°K. and have been found satisfactory whereever calculations as to the exact emission of the source are unnecessary; for spectroscopy they have the advantages that they are small, may be effectively shielded, and may be given a shape similar and comparable to that of the slit of the spectrometer. Another source is the Nernst filament, which is a thin filament made of a paste of cerium, thorium, and zirconium oxides and operated at about 2400°K. The emission of this source corresponds closely to that of a black body, but because of its delicacy and the ease with which it burns

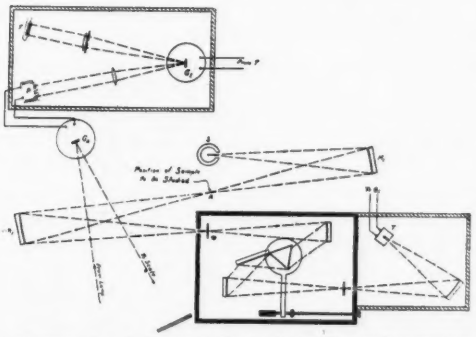

FIGURE 4.—A TYPICAL ROCK SALT PRISM SPECTROMETER, USING THE WADSWORTH MOUNTING AND A PHOTOELECTRIC AMPLIFIER (*11*)

out, is gradually going out of use. All of the foregoing sources, when operated at the temperatures mentioned, are rich in near infra-red energy. Their use in the far infra-red, which extends from about 20 to 500μ, is not to be recommended.

As may be seen from Figure 3 the far infra-red is primarily the region of gratings. Gratings, as is well known, superpose spectral orders. Table 1 shows how carefully one must be not to have any of the higher ordered spectra present while working in the far infra-red. Remembering that the intensities of the various orders n of a grating spectrum fall off as $1/n^2$, we see* that the 10th order of 10μ will still be 9×10^{-5} as compared 1×10^{-6} for the first order of 100μ. The energy of the near infra-red must therefore be eliminated completely if one is to work in the long-wave region. This is accomplished by a combination of several methods.

Fortunately, there is available as a source the Welsbach mantle, whose emissivity, while very nearly zero for the region 1–6μ, approaches the value 1 for wave-

TABLE 1

RELATIVE INTENSITIES OF A BLACK BODY AT 2000°K. [EUCKEN-WOLF (*1*)]

Wave-length, μ	*I, relative*
1.44	1
2	8×10^{-1}
5	9×10^{-2}
10	9×10^{-3}
50	2×10^{-5}
100	1×10^{-6}
200	8×10^{-8}

lengths longer than 20μ. Here is a source that gives almost the maximum energy possible for the long wavelengths, but a minimum of energy in the near infra-red. The temperature of such a mantle is estimated to be 1800°K. Obviously, the emission of the gas flame, which arises chiefly from the H_2O and CO_2 bands near 1.5, 2.7, 2.9, and 4.4μ, is superposed upon that of the mantle, and so some short wave-length energy actually is present. This energy may be partly eliminated by operating the mantle in a hydrogen flame or even an electric arc, but other methods must generally be employed to remove it comp'etely.

Receiving Devices

The most common apparatus for detecting infra-red energy is a sensitive thermopile in series with a galvanometer. The thermopile, which may be bought or made locally, usually has a receiving area that is shaped like the spectrometer slit. This area, which is made up of the "hot" junctions in a row, must be properly blackened. The most sensitive junction which is in great use consists of two alloys known as Hutchins' alloys; these are (95Bi + 5Sn) and (97Bi + 3Sb). This combination has a rating of 120μ volts per degree difference in temperature of the two junctions. Many types of couples have been used successfully, and the reader should consult the literature cited in the treatises on the infra-red before attempting to construct one. Besides the choice of materials, one has to settle the problems of the dimensions, losses of heat by conduction along the wire and losses through the air (whether to evacuate or not), the resistance, etc. Such a device obviously must be shielded from stray heat and from pressure changes. It is surprising, but very easy to demonstrate, that if the thermopile is not enclosed in a vacuum-tight container, the galvanometer will register all fluctuations of pressure in the room. In the instrument last used by the authors, for example, with the container open to the air, a deflection of 10 cm. was obtained upon opening the door to the room, due to the change of temperature caused by the adiabatic pressure change. The deflection of the galvanometer may be

* A further reduction of the intensity of the overlapping orders arises from the difference in dispersion in the first and nth orders. The relative spectral slit widths in these two cases must be considered.

amplified by any one of several methods up to the point where the unsteadiness of the building and eventually the Brownian motion of the galvanometer itself becomes noticeable (*10*).

The instrument devised by Boys, the microradiometer, is also frequently used. It is a combination of a thermocouple and galvanometer, so constructed that the suspended coil, which consists of a single turn of wire, is cut on the lower side and joined together by a suitable thermocouple. Because of its low resistance this instrument may be made extremely sensitive. It is always used evacuated in order to reduce the heat losses through the air and the resistance to the turning of the coil.

Still another receiving device is the radiometer. Here again one must proceed carefully and be fully informed if a really sensitive instrument is to be constructed. The dimensions of the entire system are small and the quartz suspension is extremely delicate. Since the radiometer depends for its action both on the presence of gas molecules and a low viscosity of the surrounding medium, the sensitivity is a function of the pressure. It usually is maximum at pressure of 10^{-1} to 10^{-2} mm. of mercury. The stiffness of the quartz fiber, the moment of inertia of the system, the pressure, etc., all play major rôles where the period of the instrument is concerned. Radiometers may of course be used together with some amplifying system but are usually so sensitive as to allow an amplification of only ten to twenty times before the unsteadinesses previously referred to become important.

Spectrometers and Methods

Many types of spectrometers are available, the selection of the one to be used being determined by the type of spectra to be measured and the degree of accuracy required. Although practically every investigator designs and constructs his instrument to suit particular needs, there are several standard spectrometers on the market. Only the general types will be outlined here.

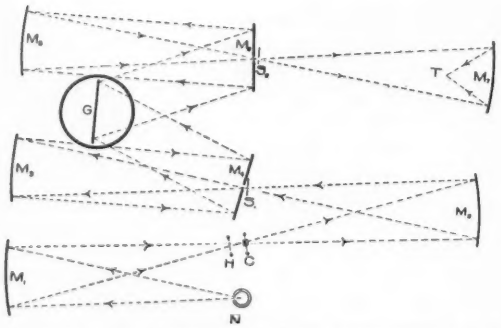

FIGURE 5.—AN ECHELETTE GRATING SPECTROMETER (*12*)

Prism spectrometers.—Figure 4 shows a typical prism instrument (*11*). The radiation which emerges from the second slit may be seen to have traversed the prism at minimum deviation. This is accomplished by the Wadsworth mirror, and greatly simplifies the calculation of the wave-length of the emergent radiation. Such an instrument may be calibrated by mapping the positions of known absorption bands such as those of H_2O, CO_2, etc., or, if a divided circle is present, the wave-lengths may be calculated. The former method is most frequently used. As is indicated in Figure 3 and Table 2, several materials are available for use as prisms. Since the resolving power of a prism is a function of the thickness of the base of the prism, and since these substances may not be had in very large pieces, the usefulness of prism spectrometers is quite limited. They are valuable, however, for a preliminary survey of the near infra-red and for many problems where the fine structure of the bands being studied is unimportant. To protect the prism, to eliminate convection currents of air, and to remove the water vapor, the instrument should be enclosed in a tight, thermally insulated box and dried with P_2O_5.

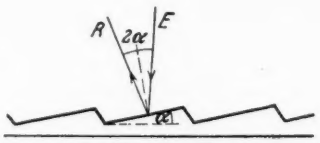

FIGURE 6.—GROOVE FORM OF AN ECHELETTE GRATING. *E* AND *R* ARE THE INCIDENT AND THE REFLECTED BEAMS; 2α IS THE BLAZE ANGLE

Echelette grating spectrometers.—If one is interested primarily in obtaining exact measurements in some particular region of the near infra-red, a spectrometer of the design shown in Figure 5 is used (*12*). It employs a reflection grating, usually one of the echelette type, which has the peculiar property of concentrating practically all of the incident energy into a restricted spectral region, called the *blaze*, on one side of the central image. This is accomplished in the process of ruling the grating by holding the cutting diamond at such an angle as to give the grooves a form very nearly like that indicated in Figure 6. The first of these gratings was constructed at Johns Hopkins University by R. W. Wood, from whom they may be purchased today. By adjusting the angle of the diamond the blaze may be placed at any desired wave-length throughout the near infra-red. These gratings are ruled upon highly polished copper blanks, and may have as many as 7200 lines/in. Since the resolution of a grating is equal to the total number of lines used, one has with a five-inch grating an instrument capable of yielding results of the highest precision. It is only with such spectrometers that there is hope of measuring accurately

TABLE 2

AVAILABLE PRISM MATERIALS AND THEIR PRACTICAL LIMITS OF USEFULNESS

Material	*Limit, in μ*
Glass	2.5
Quartz	3.5
Fluorite	9
NaCl	16
KCl	22
KBr	28
KI	31

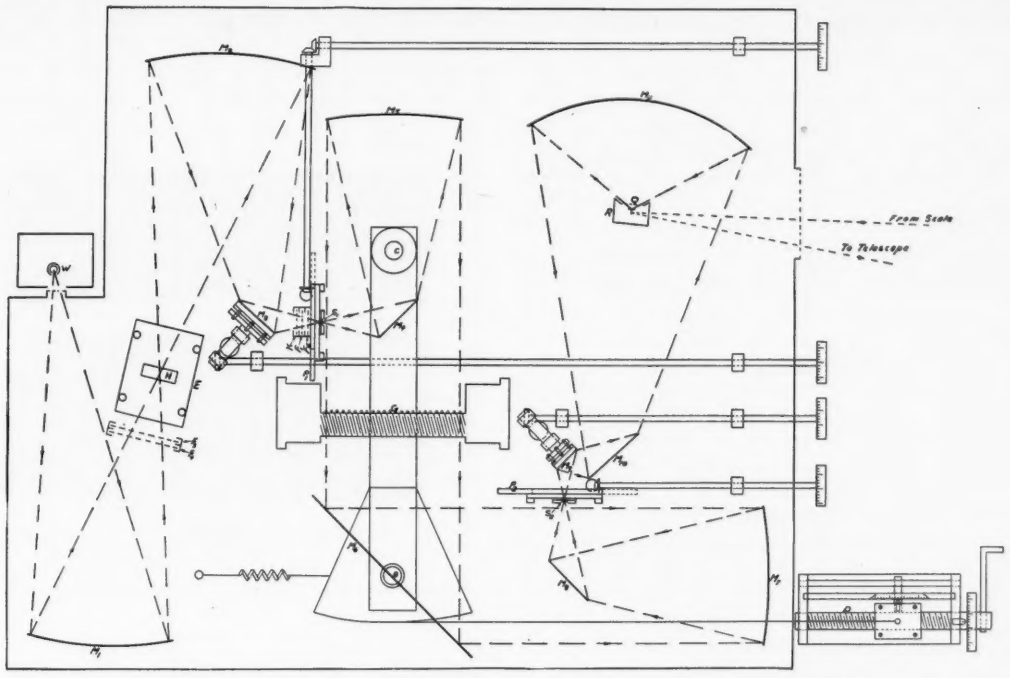

FIGURE 7.—A WIRE GRATING SPECTROMETER FOR THE FAR INFRA-RED (*14*)

the fine structure of the rotation-vibration bands, or the shifts caused by isotopes such as Cl^{37}. Since the determination of the character of the fine structure of any given band in the near infra-red is of the utmost importance for making the final decision as to its type and origin, a good echelette grating spectrometer is indispensable for work in this field.

Another form of echelette grating (*13*) consists of a pile of glass plates of suitable thickness, so arranged as to allow the radiation to be incident upon the edges which present a cross-section similar to Figure 6. Many such gratings have been devised, but so far good results have been obtained only with ruled gratings.

Wire grating spectrometers.—When one attempts to work in the far infra-red, the difficulties mount rapidly. The Johns Hopkins machines have not yet made echelettes for this region, and the University of Michigan machines have ruled successfully only a few such gratings for regions out to 100μ. Hence it is necessary for the present to rely mainly upon wire gratings similar to the original ones prepared by Fraunhofer. One of the authors (*14*) has constructed such gratings having as many as 64 wires/in. and has used them successfully throughout the region 30–180μ. Figure 7 shows a spectrometer suitable for use with these gratings. With an 8-inch grating the theoretical resolving power is 500, which at 100μ represents a wave number separation of 0.2 cm.$^{-1}$. This is never attained, of course, owing to the widths of the slits that are necessary in order to obtain a measurable amount of energy. Spectral lines have, however, been completely resolved in this region whose separation was 1.33 cm.$^{-1}$. Other lines at 150μ have been shown to be double when the separation was 0.5 cm.$^{-1}$. The authors are at present putting a spectrometer into service that promises to surpass even this.

Reflection gratings.—Many methods have been suggested for making reflection gratings for this region, but so far no results have been obtained with them. Gratings recently described by Pfund and Sanderson (*15*) show promise, however. They are prepared from the half-tone plates used in color printing and known as Levy Screens.* According to Pfund the screens need only be silvered or, better still, aluminum-plated before being used. The ruled places scatter the radiation, and the unruled portions act specularly as bright silver bars, thus producing exactly the same type of spectra as the wire grating. The accuracy with which the lines are spaced and the increased number of lines per inch, bids fair to make these gratings replace the wire gratings for use in the far infra-red.

Method of reststrahlen.—There is a method of making survey and other measurements in this part of the spectrum where the question is merely whether or not a certain body absorbs or transmits the far infra-red. It is the method originally used by Rubens in his pioneer work in this region, namely, the method of reststrahlen. A convenient spectrometer (*16*) for this

* These screens may be obtained from Max Levy, Philadelphia, Pa., up to 10 × 10 in. and containing as many as 350 lines/in.

purpose is shown in Figure 8; one of its advantages is that only very small crystal plates are necessary. Schaefer and Matossi (*1*) give a list of some 33 reststrahlen between 20 and 150μ. Although the method often can be used quickly and to advantage, its obvious disadvantages are that so few wave-lengths can be examined and that the reflected energy is not monochromatic, but may include an interval of 15 to 20μ.

Christiansen filters.—Experiments are in progress on the use of Christiansen filters in the infra-red (*17*). If a thin film of a finely powdered crystal, say quartz,

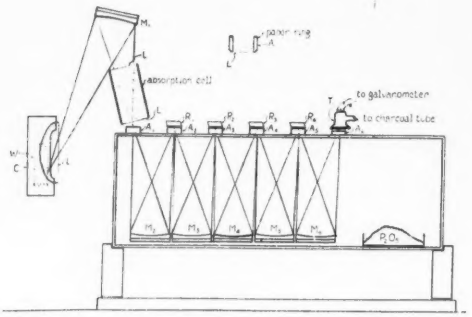

FIGURE 8.—A RESTSTRAHLEN SPECTROMETER (STRONG)

is deposited upon some suitable holder, such as a film of nitrocellulose or a plate of NaCl, it will be found to have remarkable transmission properties. If the particles are very much larger than λ_0, the true absorption wave-length of the crystal, the film will be quite opaque, because the small particles refract the radiation in all directions and thus allow very little of it to reach the slit of the spectrometer. On the short wave-length side of λ_0, however, the refractive index of the particles decreases rapidly and at some one wave-length becomes equal to 1. At this wave-length, λ_{Chr}, since the indices of the particles and surrounding medium are equal, no refraction occurs and the film shows a sharp, high transmission maximum. For quartz this maximum is decidedly sharper than the reflection band, and has a value of about 75–80 per cent. If the method is developed properly one would only need to prepare a series of such filters, and then use a source, filter, mirror, and receiving device. The method would be much simpler than that of reststrahlen.

Photographic infra-red spectrographs.—At the present time one of the most valuable sources of information concerning the fine structure of infra-red bands, is a study of the overtones and combinations of these bands which occur in the photographic region, that is, from the visible region out to 1.3μ. The recent progress in the sensitization of photographic plates has made it possible to use the large optical gratings out as far as 1.3μ, and so to obtain a degree of resolution heretofore unknown in the infra-red. As a result a great many of the fine-structure problems which were previously beyond solution are now easily mastered. The plates used are easily fogged at room temperature and must be shipped and stored at "dry ice" temperatures. It appears that we may not hope to be able to photograph

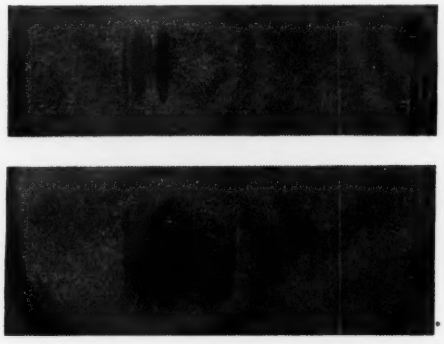

FIGURE 9.—THE ABSORPTION BANDS OF NAPHTHALENE. THE UPPER PHOTOGRAPH SHOWS THE BANDS IN THE REGION 3μ; THE LOWER, WITH LONGER EXPOSURE, SHOWS BANDS OUT TO ABOUT 6μ

much further out than 2 or 3μ since a limit is set by the intensity of black body radiation at room temperature.

Czerny's photographic method:—There does exist, however, one method of photographing farther out in the infra-red. As mentioned previously, Czerny (*18*)

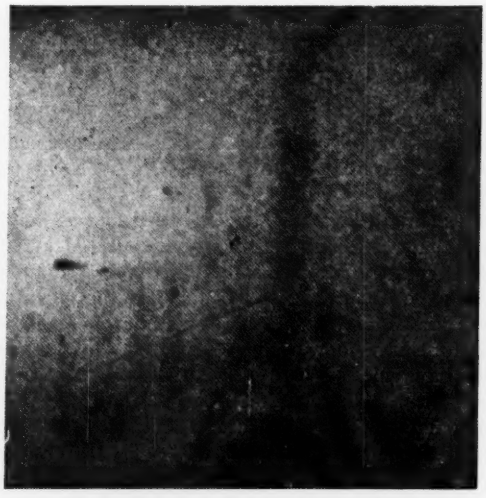

FIGURE 10.—PHOTOGRAPH OF THE 3.46μ HCl BAND (*19*)

has recently improved upon the younger Herschel's original method and obtained photographs out to 7μ. The principle is quite simple. The desired radiation is allowed to fall upon a specially prepared film having

soot on one side and naphthalene on the other. The naphthalene sublimes away from those spots where the most intense radiation falls, and the film may then be photographed by an auxiliary camera. Figure 9, taken from Czerny's original paper, shows the absorption bands due to the naphthalene out to 6μ. Figure 10, taken from a paper by one of Czerny's students (*19*), shows the 3.5μ rotation-vibration band of HCl. At this time the method had been modified, a film of oil having replaced the naphthalene. This greatly increased the sensitivity of the process, for only enough oil had to evaporate to change the color of the interference bands of the film. Before the exposure these, of course, were so broad as to make the entire film appear in one color. This method is a most promising one and deserves further development, for with long enough exposures one should be able to go quite far into the infra-red. At present the exposure time is limited to about fifteen minutes, for after that time the oil begins to flow back into the valleys where the radiation has fallen.

Experimental procedure.—In using any of the foregoing methods, other than the photographic ones, the actual procedure followed is practically the same. In an overwhelming majority of the problems attacked, investigators must be content with an exact determination of the wave-lengths of the various absorption bands and a relative determination of their intensities. Until we have more quantitative information concerning the emission of our sources, the losses of energy in the various parts of the apparatus, and the degree of "blackness" of our receiving devices, absolute intensities will be inaccessible. In studying absorption a percentage transmission curve is actually mapped out by means of some device that enables the sample to be brought into and out of the path of the radiation at will. At every wave-length, measurements are taken with the cell "out," then "in," and the ratio taken. Reflection powers are determined by comparing the deflections obtained at each wave-length from the surface of a freshly silvered mirror with those obtained from a surface of the unknown. In this way solids or liquids may readily be measured. Absorption measurements are usually carried out at room temperature although arrangements are sometimes made for controlling the temperature of the sample.

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WARPING *the* PERIODIC TABLE*

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MOST of the periodic tables in common use today are based fundamentally on two types of classification: (1) the Mendeléeff type in which long periods are presented as double rows containing eighteen elements, and (2) the electronic structure type, used effectively by Deming, in which there are eighteen columns to provide for the so-called transition metals. Both types of tables have their adherents, and both present much valuable information. On the other hand, both tend to emphasize some unnatural relationships. There never has been, and perhaps never will

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be, prepared a table which can bring out all of the normal relationships of the elements.

A fundamental weakness of all tables is emphasized by placing the elements of a family or group in the same vertical column. This emphasizes structural and valence relationships at the expense of chemical properties and chemical behavior. There is, for instance, a very marked gradation in the chemical behavior of the elements of the nitrogen family. Yet, unless this is carefully pointed out to him, the beginning student is left with the impression that nitrogen and bismuth are much alike. In chemical behavior, bismuth bears a much greater resemblance to silicon and boron than to nitrogen. Even in valence, it resembles boron more than it does nitrogen.

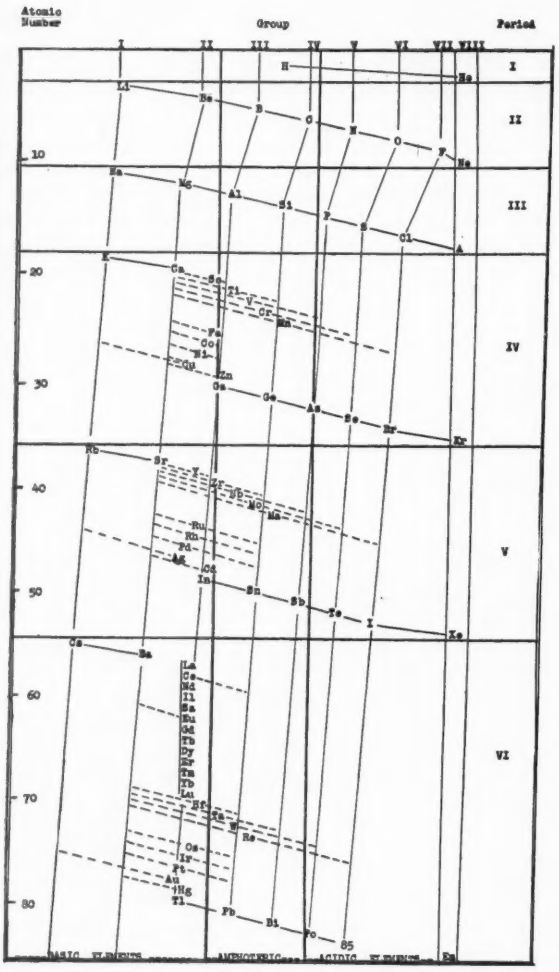

FIGURE 1.—PERIODIC GRAPH SHOWING ACIDIC, BASIC, AND AMPHOTERIC PROPERTIES

This difficulty in interpretation is sometimes lessened by presenting the diagonal relationships in the second and third periods as is shown.

Li Be B C N O F
Na Mg Al Si P S Cl

However, such a relationship cannot be continued beyond the third period because the gradation in families becomes less pronounced. Furthermore, such relationships are considerably exaggerated; silicon, for instance, resembles neither carbon nor boron in chemical properties but might be said to lie between the two. To make these cross relationships clearer, a simple device of offsetting can be used as follows.

Li Be B C N O F
Na Mg Al Si P S Cl

Such a device cannot be used in the later periods unless the transition metals are omitted, and their omission is not advisable since many important metals are included in these series.

The difficulty can be avoided by laying the table out in the form of a graph and plotting each element horizontally according to atomic number and vertically according to chemical behavior.

In such a graph one is forced to decide what property or set of properties shall be used in locating the element. For the main group elements both the physical properties of the elements themselves and the acid- or base-forming nature of the hydroxides can be used. In the case of the transition metals, however, acid- and base-forming properties vary with valence states and hence cannot be used as criteria in locating the element. The physical properties of the metal itself (hardness, ductility, malleability, and electrical conductivity) will serve to locate the metal reasonably well.

Figure 1 shows a graph of the elements constructed in this manner. It will be noted that the entire table is skewed to the left as base-forming or metallic properties become more predominant in heavier elements. However, the family relationships are definitely retained. Chemical relationships are found along the vertical lines, *i. e.*, elements directly below one another are much alike often in physical properties and generally in chemical behavior. Obviously, these relationships are neither exact nor quantitative, but they do throw together elements of similar behavior. The variable behavior of the transition metals in their different valence states is indicated by dotted lines. Just where the dividing lines should come between basic, amphoteric, and acidic elements is, of course, a matter of some conjecture.

In the opinion of the writer, a table of this type has several distinct advantages over the older types of classification.

1. It minimizes somewhat the emphasis usually given to family relationships.
2. It emphasizes gradations within families.

3. It throws together elements which have similar chemical properties.

4. It permits more effective prediction of acidic or basic natures of the elements or the hydroxides.

It is, of course, evident that such a table does not eliminate all of the difficulties encountered in other tables and no such claim is made for it. It would appear complicated to a beginning student, but if first approached through the medium of simple diagonal relationships in the short periods and the effect of sizes of atoms on properties of the elements, its significance is quickly and easily grasped even by beginners. By coloring the chart, blue on the left, red on the right, and an intermediate shade between, the acidic and basic properties of the elements are emphasized.

The most difficult task is that of determining just what criteria shall be used in locating the elements horizontally upon such a table. For all but the transition metals and the rare earths, chief reliance has been placed upon the acid- or base-forming natures of the hydroxides. Such evidence is, at best, highly qualitative, and there may be other criteria, such as ionizing potentials, which will be found to be more effective.

Incidentally, such a classification leads to another problem. We need a simple word to describe the acidic or basic natures of the elements, and we need some kind of a scale to measure these values. The writer suggests the use of the word "bascid," a contraction of base and acid to replace the awkward terminology of acid- and base-forming properties. To simplify the matter still further, a simple bascid scale might be used, ranging, say, from 1, for the strongest base-forming element, to 7, for the strongest acid-forming element. Figure 2 shows such a scale. On this scale elements forming amphoteric hydroxides would have bascid values close to 4. Hydroxides and elements could be classed on the same scale. Obviously, such a scale would be only qualitative and bears no relationship to a pH scale.

To place all of the elements and their hydroxides on such a scale in their relative positions is a task that the writer feels reluctant to attempt without the coöperation of others in the field who might regard such a proposal as worth while in clarifying some of our teaching concepts.

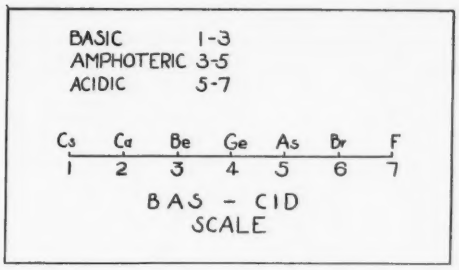

FIGURE 2.—SHOWING SUGGESTED BASCID SCALE

Such a bascid scale would, of course, simplify the use of a periodic table similar to that described in this article, both by giving more definite criteria for locating elements on the table and by describing the nature of the element more precisely. Neither table nor scale would eliminate other methods of approach to periodic classification but would merely supplement them.

An ELEMENTARY PHYSICAL CHEMISTRY EXPERIMENT *on a* THREE-COMPONENT SYSTEM

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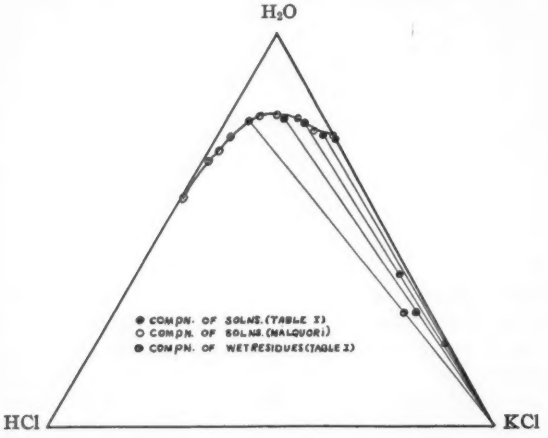
SINCE the most frequently studied three-component systems are those consisting of water and two electrolytes having a common ion (*1*), it has seemed desirable to provide an experiment for the introductory physical chemistry course involving a system of this kind. Such an experiment not only illustrates the use of triangular coördinates, but also the indirect method employed in determining the composition of the solid phase (*2*). A study of the system, potassium chloride-hydrogen chloride-water, has been used and found suitable for this purpose. Since the solutions come to equilibrium quickly, and since they may be analyzed volumetrically, the amount of time consumed in the performance of the experiment is not excessive, a pair of students being able to obtain enough satisfactory data in from six to eight hours in the laboratory.

The experimental procedure involves an adaptation of the usual method employed in physical chemistry

exercises dealing with solubility measurements (*3*). The wet residue method of Schreinmakers (*2*) is employed in determining the composition of the solid phase. A suitable procedure and sample of data obtained are given below.

EXPERIMENTAL

Apparatus and Materials.—Glass-stoppered bottles, constant temperature bath, potassium chloride, hydrochloric acid, 0.2 *N* silver nitrate, 0.1 *N* sodium hydroxide, phenolphthalein, and 5 per cent. sodium chromate.



Procedure.—A series of hydrochloric acid solutions, having normalities of approximately 6, 3, 2, and 1, are prepared. About 50 cc. of each of these solutions are placed in glass-stoppered bottles, to which 20–25 g. of potassium chloride have been added. These solutions are saturated with the salt at about 30°, and are placed in a constant temperature bath regulated at 25°, and allowed to come to equilibrium with frequent vigorous shaking. A similar quantity of freshly boiled distilled water is saturated with potassium chloride at 25° in like manner.

When equilibrium is established, approximately one-g. samples of the saturated solutions are withdrawn by means of a pipet, the tip of which is covered with a piece of filter paper. The pipets are discharged into small glass-stoppered bottles, and the samples weighed. The weighed samples are then rinsed into flasks, diluted to about 100 cc., and titrated, first with standard sodium hydroxide, and then with standard silver nitrate. After the titration with sodium hydroxide, in which phenolphthalein is used, the indicator color is destroyed by adding one drop of very dilute nitric acid to the solution on the tip of a stirring rod. (*Caution:* silver chromate will not precipitate in an acid solution.) The chromate indicator is then added, and the titration with silver nitrate carried out in the usual manner.

A sample of the moist residue is obtained from each bottle, and analyzed in the same way for acid and chloride.

From these titrations the per cent. by weight of potassium chloride, of hydrogen chloride, and of water in each solution is calculated, and the data plotted on a triangular graph. Tie-lines are drawn between the points on the curve corresponding to the composition of each solution and its wet residue. All of the tie-lines are extended until they intersect. The point of intersection gives the composition of the solid phase.

TYPICAL RESULTS

Below are given the results of a typical experiment as performed by students following the directions suggested above. In working the experiment, a large beaker of water, regulated by hand to 25 ± 0.2°, was used for a constant temperature bath; the materials used were Mallinckrodt's "Analytical Reagent" potassium chloride and Merck's C.P. hydrochloric acid with no attempt at further purification; each solution was left in the 25° bath with intermittent shaking for thirty minutes or longer.

TABLE 1

Composition of Solutions			*Composition of Residues*		
%KCl	*%HCl*	*%H₂O*	*%KCl*	*%HCl*	*%H₂O*
26.60	0.00	73.40			
23.25	2.46	73.29	77.52	1.38	21.10
17.20	5.16	77.64	58.80	2.85	38.35
12.61	9.12	78.25	67.1	4.0	28.9
5.07	17.65	77.28	64.4	6.7	28.9

Table 1 gives the composition of the solutions and the corresponding wet residues expressed in per cent. by weight. These data are plotted in the figure which also includes a plot of the data of Malquori (*4*) for comparison.

It is evident from the figure that the data obtainable in this experiment are reasonably reliable even when no extreme precautions are taken to insure constant temperature and complete saturation of the solutions, and that it provides an adequate illustration of the principles involved. It has been found to be a valuable supplement to the usual experiment on three-component systems (*5*).

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The METAL CARBONYLS*

III. CONSTITUTION. IV. PROPERTIES

WM. E. TROUT, JR.

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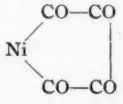
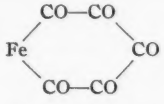
III. CONSTITUTION

FROM the time of the discovery of the first of the metal carbonyls, the problem of the constitution of these compounds has attracted the attention of a number of able investigators. Although the metal carbonyls are generally considered to be coördination compounds, agreement concerning their structure is apparently not yet unanimous. It will, therefore, be of interest to review some of the concepts that have been proposed.

Mond and Nasini (*31*) in 1891 first considered nickel carbonyl to be a compound of octavalent nickel, in accordance with the position of nickel in the Eighth Group of Mendeléef. The resemblance of nickel carbonyl to organic compounds, its high molecular refraction, and the manner in which certain reagents decompose it, led Ludwig Mond (*32*) in 1892 to propose the formulas

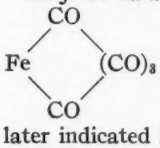


and



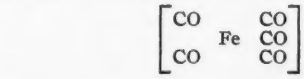
for nickel carbonyl and iron pentacarbonyl, respectively. Agreement with this concept was voiced by Armstrong (*33*), Gladstone (*34*), and Friend (*35*).

A. J. F. da Silva (*36*) in 1896 proposed the formula



for iron pentacarbonyl. However, he later indicated his belief that the carbon atoms do not form a chain but are connected directly to the metal atom.

A. von Werner (*37*) in 1909, in his "Neuere Anschauungen," suggested the formula,

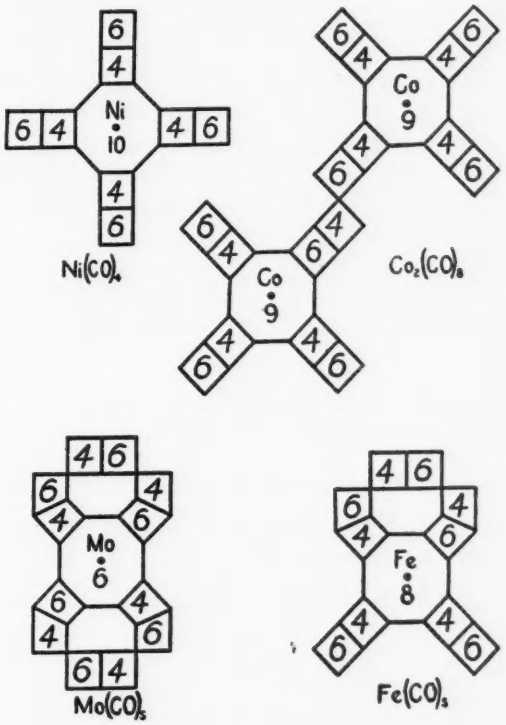


in accordance with his theory of coördination compounds—"Nebenvalenzbindungen."

By 1910, L. Mond (*38*) was apparently inclined to discard the ring formulas for the coördination formulas of Werner, but in a report in 1930, his son, Robert L. Mond (*1*), refers again to evidence favoring the ring formulas.

Langmuir (*39*) first suggested, in 1921, that there were eighteen electrons in the outer levels of the metal atoms in $Ni(CO)_4$, $Fe(CO)_5$, and $Mo(CO)_6$. As we shall see, this concept became the basis of subsequent models of the metal carbonyl molecules.

Blanchard and Gilliland (*40*) in 1926 suggested formulas represented by the following diagrams, where



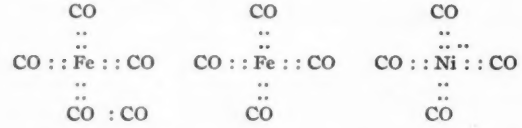
corners of squares represent electron pairs, and numbers represent kernel charges of the atoms. This concept of the metal carbonyls was extended to $Co_2(CO)_8$, $Fe_3(CO)_{12}$, $HCo(CO)_4$, $KCo(CO)_4$, $H_2Fe(CO)_4$, etc., by Blanchard and Windsor in 1934.

Hieber and his co-workers (*41*), as early as 1928, in a series of studies, were led to regard the metal carbonyls as true coördination compounds.

Manchot (*42*), in 1926, found evidence to indicate that the metal carbonyls are coördination compounds and in 1929 suggested formulas for iron pentacarbonyl,

* This is the second of a series of four articles concerning the metal carbonyls. The author reserves all rights to these articles.

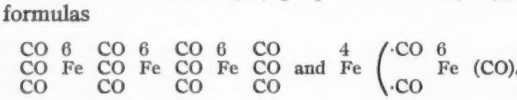
iron tetracarbonyl, and nickel carbonyl, similar to the structures suggested by Hieber.



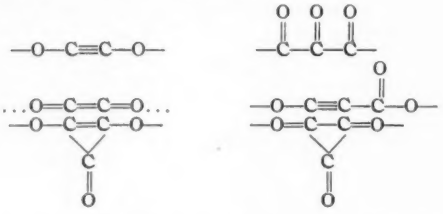
Brill (*43*), from X-ray studies, proposed the following structure for $Fe_3(CO)_9$.

The superscript indicates the coördination number of the iron atom.

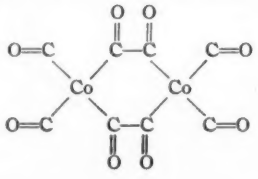
Hieber and Becker (*44*) proposed for $Fe_3(CO)_{12}$ the formulas



Differing with these concepts, Reihlen (*45*), as late as 1928, considered the carbonyl groups to be constituents of hypothetical acids, such as:

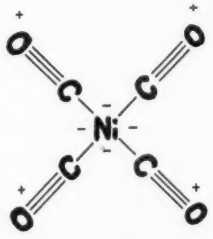


The iron and nickel carbonyls were considered to be derivatives of the bivalent metals and acids of this nature. Schubert (*46*), in 1933, supported Reihlen's views and suggested a formula for cobalt tetracarbonyl:

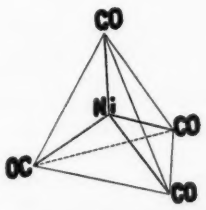


As late as 1930, Sugden (*47*), on the basis of parachors calculated from the early surface tension values of Ramsay and Shields, found evidence to support the ring formula of nickel carbonyl. The calculation, however, was admitted to be not too reliable in choosing between the ring and centric formulas.

In spite of the confusion which apparently exists concerning the nature of the metal carbonyls, the Werner-Hieber-Manchot theory is generally accepted. This theory holds that the metal carbonyls are coordination compounds, in which the central metal atom is not an ion. In fact, many investigators of the structure of nickel carbonyl appear to accept this theory as proved and are concerned with the problem of whether, for example, the nickel carbonyl molecule has plane or tetrahedral structure. Dadieu and Schneider (*48*), from Raman spectra data, find support for II. Pauling (*49*), from consideration of quantum theory, finds support for I. Duncan and Murray (*50*), from Raman



I. PLANE MODEL



II. TETRAHEDRAL MODEL

spectra and the study of vibrating models of the molecule, find evidence to support I.

Sidgwick (*51*), in a recent paper, presents a summary of the most widely accepted views of the constitution of many of the metal carbonyls and nitrosyls. His conclusions are sufficiently interesting to be presented in some detail here. The reader should refer to his paper for detailed bibliography.

Sidgwick points out that carbon monoxide is the electron donor and occupies one coördination position in the metal. This view is supported by the electric dipole moments of the symmetrical carbonyls (which are nearly zero), by interatomic distances, by the heats of formation, by the force constants of the bonds, and by the parachor. The view is also in agreement with Langmuir's theory of the structure of carbon monoxide (*52*). The electronic conception of carbon monoxide may be represented in two ways, :C:::O: or $\dot{C}\equiv\bar{O}$, where the triple bond between carbon and oxygen is indicated. When the carbon monoxide forms a coördinate link with the metal atom and acts as donor of the pair of electrons, the structure of such a bond may be represented similarly: M:C:::O: or $\dot{M}—C\equiv\bar{O}$. It is not clear whether the carbon monoxide is coördinated through the carbon atom or through the oxygen atom. Anderson (*53*) adduces some evidence to support coördination through the carbon atom. In any event, the M:C:::O: group must be co-linear, otherwise rotation of the groups would give rise to an electric moment. Since carbon monoxide will replace water or ammonia from complex compounds, the coördinate link of carbon monoxide to metal must be by means of a single electron pair. Furthermore, Raman spectra data have shown that in the metallic carbonyls, the carbon is joined to oxygen by a triple link. In view of these facts, Sidgwick regards the structure M:C:::O: as reasonably well established.

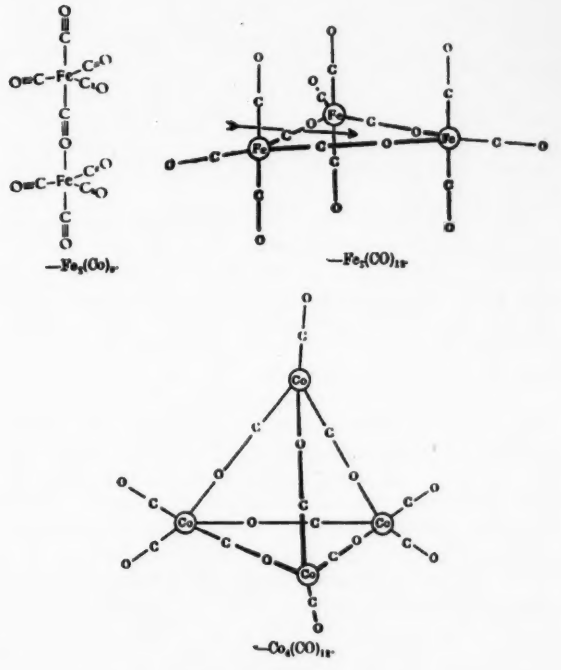
Sidgwick also proposes an equation which serves to

correlate the known metal carbonyls and appears to predict the presence of other carbonyls. The equation is based upon the observation that in the monomolecular carbonyls, $Ni(CO)_4$, $Fe(CO)_5$, $Cr(CO)_6$, $Mo(CO)_6$, and $W(CO)_6$, the effective atomic number of the metal is that of the next rare gas. These and also the "polymolecular" carbonyls are in agreement with the equation

$$G - \frac{xm + 2y}{x} = x - 1, \qquad (1)$$

where "G" is the atomic number of the next inert gas succeeding the metal in the Periodic Table, "m" is the atomic number of the metal, "x" is the number of metal atoms in the molecule, and "y" is the number of carbonyl groups in the molecule, which may be represented by the general formula, $M_x(CO)_y$. It may be shown that the formula applies to the carbonyls listed above, and also to $Fe_2(CO)_9$: $Fe_3(CO)_{12}$, $Co_2(CO)_8$, $Co_4(CO)_{12}$, $Ru(CO)_5$, and $Ru_2(CO)_9$.

Sidgwick suggests that the coördination of the polymolecular compounds may take place through the carbonyl group. For example, the structures of $Fe_2(CO)_9$, $Fe_3(CO)_{12}$, and $Co_4(CO)_{12}$ are suggested to be as follows.



It is interesting to note that Equation 1 predicts the existence of the hitherto unreported compound, $Fe_4(CO)_{14}$.

IV. PROPERTIES

General Behavior (*1*).—The resemblance of the metal carbonyls to organic compounds has already been pointed out. In the lists of solvents, organic compounds occur much more frequently than inorganic. Furthermore, the metal carbonyls are not salt-like; they are poor conductors of electricity; and they are diamagnetic in contrast with the salts of the metals.

The general behavior of the compounds is in accord with the view that the metal carbonyls are coördination compounds. The coördination number of nickel carbonyl is four, while that of the hexacarbonyls of chromium, molybdenum, and tungsten is six. The coördi-

ALWYN MITTASCH (1869-)

Alwyn Mittasch is the son of a school teacher, and was himself a school teacher. When twenty-seven, he turned from the study of philosophy under Wundt to the study of chemistry under Wilhelm Ostwald and Max Bodenstein, becoming Ostwald's assistant. Attracted into industrial chemistry, Dr. Mittasch entered the employ of the *Badische Anilin- und Sodafabrik* where he advanced rapidly. He was the founder of the Research Laboratories of the *I. G. Farbenindustrie* at Oppau, and was its director from its inception in 1918 until 1933, when he was made Director Emeritus.

Dr. Mittasch is a man of great energy and varied interests, outstanding among which are studies of catalysis and the metal carbonyls. Besides his election to positions of responsibility, Dr. Mittasch has received many honors. He was president of the Deutsches Bunsengesellschaft, received several honorary degrees, and was honored with both the Bunsen medal and the Liebig-Kekulé medal. On Dr. Mittasch's sixtieth birthday, Wilhelm Ostwald paid tribute to his pupil in an interesting address, which may be found on the first page of the *Zeitschrift für Elektrochemie* for 1930.

nation numbers of the complex derivatives of iron carbonyl may be either four or six.

As might be expected, the carbon monoxide radical may be replaced by other groups to form substitution compounds. Iron and cobalt carbonyls show a greater tendency to form these compounds than do the other carbonyls. Iron and cobalt carbonyls, in general, show many properties which apparently are not possessed by the other carbonyls. The formation of nitrosyl carbonyls and carbonyl hydrides is of special interest. Furthermore, in accordance with its unsymmetrical structure, iron pentacarbonyl has a measurable dipole moment, whereas the dipole moments of the symmetrical hexacarbonyls and of nickel carbonyl are practically zero.

WILHELM MANCHOT (1869–)

Wilhelm Manchot studied at Strassburg and at Munich, and taught at the Universities of Halle, Göttingen, and Würzburg before he was called to Munich in 1914. From organic chemistry, in which he made significant contributions to the knowledge of autoxidation, Professor Manchot's interest turned to problems in inorganic chemistry. He was Professor of Inorganic Chemistry and Director of the Inorganic Chemical Laboratories of the *Technischen Hochschule* of Munich until his retirement in 1935 as Professor Emeritus. An interest in the parallelism between the chemistry of nitric oxide and carbon monoxide led Professor Manchot to make important contributions to the study of the metal carbonyls and nitrosyls.

There is much variation in the stability of the metal carbonyls. Nickel carbonyl begins to liberate carbon monoxide and nickel at 0° in a vacuum, and the decomposition becomes rapid above 60° in an inert gas under atmospheric pressure. The decomposition, as predicted from the equation, is markedly inhibited by carbon monoxide.

$$Ni(CO)_4 \rightleftharpoons Ni + 4CO$$

$$K = \frac{P_{Ni} \times P^4_{CO}}{P_{Ni(CO)_4}}$$

It will be observed from Table 1 that cobalt carbonyl decomposes at about 60°, whereas the iron carbonyls and the hexacarbonyls decompose at temperatures between 100° and 150°.

In their sensitivity to oxygen and oxidizing agents the metal carbonyls vary from the pyrophoric nickel carbonyl to the relatively inert hexacarbonyls. In general, the products of these reactions are salts of the metals and free carbon monoxide. With strong oxidizing agents, and in the presence of alkali, some of the carbon monoxide is oxidized to carbon dioxide.

The relative inertness of the metal carbonyls to the usual dilute acid and alkali is consistent with their resemblance to organic compounds.

The metal carbonyls have been used in the preparation of aldehydes and ketones from Grignard reagents; in the polymerization of hydrocarbons, such as butadiene; and also in the reduction of certain organic compounds.

Some of the properties of the carbonyls have been tabulated for convenience in Table 1. A brief discussion of the properties of each of the eleven true metal carbonyls may be helpful in understanding these unusual compounds.

Nickel Carbonyl.—Nickel carbonyl is a colorless, volatile, highly refractive liquid, with a large coefficient of cubical expansion. Its magnetic rotatory power is said to be greater than that of all substances except phosphorus. The vapor burns with a luminous flame in which free nickel is present, and from which is obtained a continuous spectrum.

The decomposition of nickel carbonyl has been the subject of much interest. If heated rapidly, pure nickel carbonyl decomposes rapidly. Mirrors are formed on the walls of the vessel. Mittasch (*54*) showed the decomposition to be of the first order and concluded that reaction takes place only on the walls of the vessels. Garratt and Thompson (*55*) prefer to regard the effect of the wall as evidence of a chain reaction which they represent as follows

1. $Ni(CO)_4 \rightarrow Ni(CO)_3 + CO$
2. $Ni(CO)_3 \rightarrow Ni + 3CO$
3. $Ni(CO)_3 + CO \rightarrow Ni(CO)_4$

Reaction 3 indicates the retarding effect of carbon monoxide on the decomposition, which is in agreement with experiment. The slight retardation observed on increasing the surface of the reaction vessel was regarded as due to the breaking of reaction chains.

The photochemical decomposition of nickel carbonyl by light of wave-length shorter than 3900Å. was

TABLE 1

SOME PROPERTIES OF THE METAL CARBONYLS

Metal Carbonyl	*Discoverer and Date*	*Color and State*	*M. P.*	*B. P.*	*Vapor Pressure*	*Specific Gravity*	*Temp. of Formation*	*Decomposition*
$Ni(CO)_4$	Mond, Langer, Quincke 1890	Water-clear liquid	−25°	43.2°	238 mm.[15°]	$1.31032^{20°}$	30–50° (1 atm.) (Mond)	To CO and Ni above 50° at 1 atm. At 0° in vac.
$Co_2(CO)_8$	Mond, Hirtz, Cowap 1908	Orange crystals	51°	Decomp. *ca.* 52°	0.72 mm.[15°]	1.73	220° at 150 atm. 150° at 40 atm. (Mond)	To CO and Co above 60°. To Co and $Co_3(CO)_{12}$ at 50–60°.
$Co_3(CO)_{12}$	Mond, Hirtz, Cowap 1908	Jet black crystals	Decomposed above 60°				60° from $Co_2(CO)_8$ (Mond)	To CO and Co above 60°.
$Fe(CO)_5$	Berthelot (Mond) 1891	Water-clear liquid	19.5	104.6	25.9 mm.[18-19°]	$1.453^{20°}$	173° at 200 atm. (Mond)	To $Fe_2(CO)_9$ by light. To CO and Fe above 130°.
$Fe_2(CO)_9$	Mond, Langer 1891	Golden, or orange-yellow hexagonal plates	Decomposed at 100°		Not measurable	$2.085^{18°}$	Light on $Fe(CO)_5$ at room temp. (Mond)	To $Fe(CO)_5$, Fe, and Co at 100°. To $Fe_3(CO)_{12}$ and $Fe(CO)_5$ in sol. at 95°.
$Fe_3(CO)_{12}$	Dewar, Jones 1905	Dark green tables with square borders	Decomposed at 140–150°			$1.996^{18°}$	From $Fe_2(CO)_9$ at 60° (Dewar)	To Fe and CO at 150°.
$Cr(CO)_6$	Job, Cassal 1926	Colorless orthorhombic crystals	Sublimes at room temp.		60.6 mm.[100-4°]		0–4° (Job)	To CO and Cr by light. To Co and Cr at 200°. Explodes at 210°.
$Mo(CO)_6$	Mond, Hirtz, Cowap 1908	Colorless crystals	Sublimes at 30–40°		43.2 mm.[100-8°]	$1.96^{15°}$	200° at 200–250 atm. (Mond) 0–4° (Job)	To CO and Mo above 150°.
$W(CO)_6$	Job, Rouvillois 1928	Colorless crystals	Sublimes at 50°		14.4 mm.[100-4°]		0–4° (Job)	To CO and W above 100°.
Ru(CO)	Mond, Hirtz, Cowap 1908	Orange-yellow crystals					300° at 300–400 atm. (Mond)	To CO and Ru on heating.
$Ru(CO)_2$	Mond, Hirtz, Cowap 1908	Chocolate brown powder					250° at 350 atm. (50 hours) (Mond)	To CO and Ru on heating.
$Ru(CO)_5$	Manchot, Manchot 1936	Colorless volatile liquid	−22°				300° at 400 atm. (Manchot)	To CO and Ru above 150°.
$Ru_3(CO)_9$	Manchot, Manchot 1936	Orange-red pseudohexagonal plates					Light on $Ru(CO)_5$ or heat at 50° (Manchot)	
$Ru(CO)_x$	Manchot, Manchot 1936	Green					Formed with $Ru_3(CO)_9$	

explained similarly, according to the equations

1. $Ni(CO)_4 + h\mu \rightarrow Ni(CO)_3 + CO$
2. $Ni(CO)_3 \rightarrow Ni + 3CO$
3. $Ni(CO)_3 + CO \rightarrow Ni(CO)_4$

Little decomposition by light was observed in the vapor phase, a result which is in accordance with the suggested recombination indicated by equation 3. In solutions of carbon tetrachloride, hexane, and cyclohexane, the insolubility and consequent escape of carbon monoxide was offered as an explanation of the increased decomposition.

To explain some of the properties of nickel carbonyl, Berthelot (*56*) suggested that two thermal decompositions may take place, according to two reactions: the first a slow, endothermal reaction, $Ni(CO)_4 = Ni + 4CO$; and the second, a rapid, exothermal reaction which was more significant at higher temperatures, $Ni(CO)_4 = Ni + 2C + 2CO_2$.

The reaction of nickel carbonyl with oxygen (*57*) still requires adequate explanation. If allowed to stand in air, the carbonyl may burst into flame with a mild explosion. The explosion is seldom violent if the gas is unconfined. Occasionally, however, the carbonyl may be safely handled in air for a short time without explosion. Apparently a temperature of about 60° is necessary to bring about explosion of nickel carbonyl with dry air. A slow exothermal oxidation at low temperature, by which the gas is gradually heated to the kindling point, may explain the spontaneous combustion. When the carbonyl is confined in a glass-stoppered bottle, air enters and reaction takes place slowly with the formation of a solid, the composition of which varies and the nature of which still requires adequate explanation. When slowly oxidized in the presence of a base, nickel carbonyl forms a basic carbonate of nickel.

The ease of oxidation of nickel carbonyl is indicated by the fact that it reduces ammoniacal solutions of copper and nickel salts, as well as platinic chloride.

Chlorine, bromine, iodine, and cyanogen form corresponding nickelous salts and liberate carbon monoxide (*58*). The reaction with bromine or chlorine water may be used for quantitative estimation of the carbonyl.

$$Ni(CO)_4 + Br_2 \rightarrow NiBr_2 + 4CO$$

Ammonia and nitrogen do not react with the carbonyl (*59*). Nitric oxide forms a pale blue, almost white, solid at temperatures between −11° and 0°, and liberates carbon monoxide. This reaction appears to be complex. Nitrogen trioxide forms a red solid at −78°. Nitrogen peroxide apparently forms a mixture of nickel nitrite and nickel nitrate, liberating carbon monoxide and a trace of carbon dioxide. Nitric acid reacts much as the halogens, forming nickel nitrate

and liberating carbon monoxide, accompanied by some carbon dioxide. Hydroxylamine and hydrazine form white solids of unknown nature (*60*).

The reaction of nickel carbonyl with carbon disulfide is complex (*61*). Nickel sulfide and carbon are among the products. Sulfur and hydrogen sulfide form nickel sulfide. Dry nickel carbonyl over concentrated sulfuric acid detonates, liberating carbon monoxide and forming nickel sulfate. When diluted with nitrogen, the reaction proceeds quietly. Some of the sulfuric acid is reduced.

WALTER HIEBER (1895–)

Walter Hieber early was attracted to the chemistry of the complex compounds and received his doctorate at Tübingen under Professor R. F. Weinland. After serving on the staffs of the Universities of Würzburg, Jena, Heidelberg, and Stuttgart, Professor Hieber was called to the post at Munich left vacant by the retirement of Professor Manchot. Although still a young man, Professor Hieber is credited with nearly sixty reports on research, of which about thirty are concerned with the metal carbonyls and their derivatives.

Nickel carbonyl reacts also with ICl, ICl_3, and PH_3.

Nickel carbonyl dissolves in iron pentacarbonyl and there is some evidence that $FeNi(CO)_8$ is formed when this solution is subjected to light.

Iron Carbonyls.—Iron pentacarbonyl is a clear, colorless liquid; however, the presence of small amounts of the enneacarbonyl frequently gives it a yellow or orange color. It is more stable than nickel carbonyl.

In light of wave-length shorter than 4100Å., that is in the violet and ultra-violet range, iron pentacarbonyl decomposes to form the enneacarbonyl. Garratt and Thompson (*55*) support the following mechanism earlier suggested by Dewar and Jones for this reaction:

$$Fe(CO)_5 + h\mu \rightarrow Fe(CO)_4 + CO$$

$$Fe(CO)_4 + Fe(CO)_5 \rightarrow Fe_2(CO)_9$$

Iron pentacarbonyl decomposes slowly in air. Its vapor burns, liberating a thick brown smoke of Fe_2O_3. Mixtures of the vapor and air are explosive. The compound is not particularly inflammable, although it may be ignited by hot bodies.

The reactions with halogens, oxidizing agents, dilute acid, and ammonia, resemble those of nickel carbonyl.

The pentacarbonyl reduces nitrobenzene to aniline, ketones to alcohols, and benzil to benzoin. Carbon tetrachloride liberates carbon monoxide and phosgene, and at the same time ferric chloride is formed.

Peroxides liberate carbon monoxide and form ferric oxide. This reaction may be used as a test for peroxides (*62*).

The six-sided golden or orange-yellow plates of iron enneacarbonyl are non-volatile, insoluble in water, and, in contrast with the preceding compounds, are also insoluble in ether, benzene, and benzine. They are somewhat more soluble in ethyl alcohol, acetone, and pyridine. The crystals are stable when moist. When dry, they are unstable in air.

The so-called iron tetracarbonyl, $Fe_3(CO)_{12}$, may be crystallized from toluene, benzene, or nickel carbonyl as dark green monoclinic prisms or tables with square borders, showing strong dichroism from dark green to bright green. The compound oxidizes readily in solution in the presence of air or oxygen.

Cobalt Carbonyls.—Cobalt tetracarbonyl, $Co_2(CO)_8$, forms orange, transparent crystals, stable in hydrogen and carbon monoxide, but readily decomposed by air to form a violet basic carbonate. Oxidizing agents liberate carbon monoxide as with the other carbonyls.

The crystals of cobalt tricarbonyl, $Co_4(CO)_{12}$, are jet black and insoluble in the usual solvents.

*Ruthenium Carbonyls.**—The ruthenium carbonyls, orange-yellow RuCO and chocolate-brown $Ru(CO)_2$, differ surprisingly from the other carbonyls in that they

* Recently, the nature of the ruthenium carbonyls has been greatly clarified by the work of Manchot and Manchot, who reported the preparation of three carbonyls which appear to be analogous to the carbonyls of iron. Ruthenium pentacarbonyl, $Ru(CO)_5$, is a clear, colorless, volatile liquid, which forms crystals melting at −22°. The compound is insoluble in water, and is readily soluble in organic solvents. Its solution in glacial acetic acid becomes lilac colored in direct sunlight. The carbonyl is very sensitive to light, releasing carbon monoxide and forming $Ru_2(CO)_9$. The enneacarbonyl is formed also when $Ru(CO)_5$ is heated to 50°. When it is heated above 150° in air, the pentacarbonyl decomposes into ruthenium and carbon monoxide.

$Ru_3(CO)_9$ forms orange-red pseudohexagonal plates. When heated in dry nitric oxide, it forms red crystals of $Ru(NO)_5$, usually contaminated with $Ru(CO)_5$.

$Ru(CO)_2$, formed when $Ru(CO)_5$ is converted into $Ru_2(CO)_9$, is apparently analogous to $Fe_3(CO)_{12}$. [*Z. anorg. Chem.*, **226**, 385 (1936).]

are soluble in water. The dicarbonyl is insoluble in benzene.

The Hexacarbonyls.—$Cr(CO)_6$, $Mo(CO)_6$, and $W(CO)_6$ (*63*) are unusually stable, forming colorless, strongly refractive, easily sublimed, isomorphous, orthorhombic crystals. At ordinary temperatures, oxidizing agents such as sulfuric acid, chlorine, and bromine, are without action. Fuming nitric acid, however, decomposes the carbonyls rapidly with oxidation of the metals.

The symmetry of the structures of the hexacarbonyls would lead us to expect that their properties might resemble those of the equally symmetrical nickel carbonyl. In accordance with this view, we find that, at higher temperatures, halogens react with the hexacarbonyls much as they do with nickel carbonyl. In the presence of alkalies, or other substances which bind carbon dioxide, the hexacarbonyls, like nickel carbonyl, react with oxygen to form carbonates. Furthermore, neither nickel carbonyl nor the hexacarbonyls have been made to form carbonyl hydrides.

To sum up, although investigators propose differing concepts, the metal carbonyls are generally regarded as coördination compounds, and this interpretation is largely supported by their physical and chemical behavior.

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AUTOMATIC HYDROGEN SULFIDE GENERATOR*

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SUPPLYING hydrogen sulfide gas for a small class in qualitative analysis is usually a difficult problem in a small laboratory. This problem was solved at Upper Iowa University by using the commercial product "Aitch-tu-ess" (H_2S) as the source of the gas and setting up the apparatus pictured in the accompanying drawings. This method was found to be both economical

* Presented before annual meeting of Iowa Academy of Sciences at Dubuque, Iowa, April 16, 1937.

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and convenient and eliminated practically all of the undesirable odor which so often accompanies a qualitative analysis laboratory.

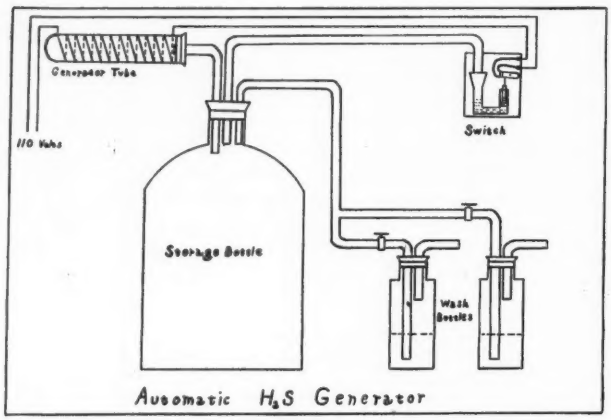

FIGURE 1

The gas is generated in a 25 × 300 mm. Pyrex tube, covered with $^1/_{32}$″ sheet asbestos and wound with 55–60 turns of Nichrome wire gage No. 24, having a resistance of 1.59 ohms per foot. Sixty cycle alternating current of 110 volts was used.

As the gas is generated it flows into the storage bottle where it is maintained at a relatively constant pressure by the use of an automatic pressure switch. Several wash bottles may be connected to the storage bottle; thus several students have access to the gas supply at the same time. Four individual wash bottles were used on the original apparatus.

The automatic switch consists of a short glass tube mounted on a pivot in such a way that an increase or decrease in pressure in the storage bottle will "make" or "break" the heater coil circuit. The mounting (*A*) for the glass tube was cut from sheet copper and mounted on the baseboard with a screw, with a washer between the mounting and baseboard to hold the switch away from the baseboard. The switch mounting is connected with the glass float by means of a sheet copper arm (*B*). The float consists of a glass vial with a cork stopper. The arm (*B*) is connected to the stopper by a pin. Mercury is used in the float to act as a counterbalance and makes the switch sensitive to a slight pressure change.

A short tube, made by melting a test-tube in half and sealing the end, acts as the holder for the brass (copper may be used) electrodes and the globule of mercury. It is fastened to the mounting (*A*) with rubber bands. Brass contacts $^1/_8$″ wide are held in place by the stopper and form a small gap. When the pressure decreases the mercury level falls, causing the float to drop, which in turn pulls the contact end of the switch downward and the globule of mercury in the short test-tube closes the circuit between the two electrodes. As soon as the pressure is built up in the storage bottle the mercury level is raised, causing the float to push the switch in an upward direction and the mercury globule returns to the other end of the tube, thus opening the circuit.

A separatory funnel was used for the mercury well, so a slight change of pressure produces a large rise or fall of the level of the mercury in the tube supporting the float.

A bottle of about fifty liters capacity may be found in any laboratory and makes an excellent storage bottle. The Pyrex tube costs seventeen cents and a twenty-five-foot spool of Nichrome wire can be purchased for fifty cents. The remainder of the apparatus may be found in any chemistry laboratory.

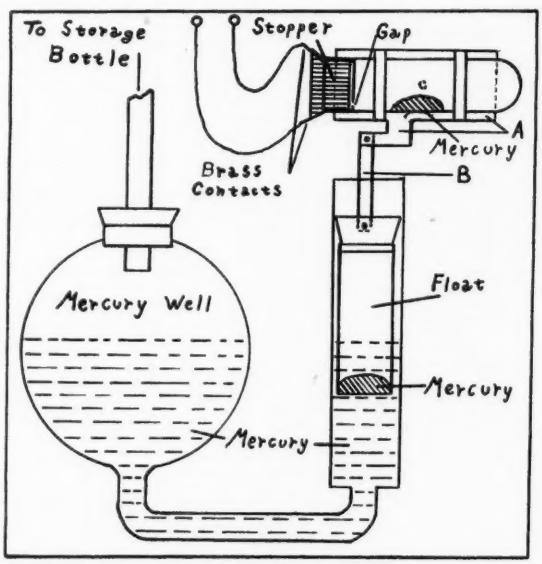

FIGURE 2

This generator has been in use for eighteen weeks and supplies hydrogen sulfide gas for a class of twenty students at a cost of approximately fifty cents per student per semester. The capacity of the system depends upon the size of the generating tube and the storage bottle.

Knowledge comes by eyes always open and working hands; and there is no knowledge that is not Power. Do valiantly, and hope confidently and wait patiently.—JEREMY TAYLOR

The SCIENCE TEACHER'S JOB*

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THE business of teaching science today is a real job. This statement will probably not be questioned by any teacher whether he or she be teaching in a public school, a college, or a university. Previous generations of science teachers who began the work which we now carry on, met their chief difficulties in (1) convincing educational leaders that science had educational values and in (2) finding or creating instructional materials for their classes. The present generation of science teachers face problems of a different nature. We are to think about some of these problems today. Let us first review some of the fundamental factors; for example (1) the enormous accumulation of scientific information and technic during the past three decades, (2) the increase in enrolment of pupils of high-school age from about ten per cent. to about fifty per cent. during a period of thirty years,[1] and (3) profound changes in our economic and social life during the same period, especially during the financial depression. The success of our science program in the schools depends upon how we evaluate these fundamental factors.

The effect of the first factor in determining the content of college textbooks in general chemistry, for example, becomes evident, when one compares books which were written twenty-five or thirty years ago with those recently written.[2,3] The older books contain essentially descriptive material with very little correlation. The modern books contain the descriptive material and principles and theories in ever-increasing amounts. This increase in the content of college textbooks of chemistry is due, also, to the fact that more students are coming to college with high-school preparation in chemistry. The increase in content of high-school textbooks of chemistry has kept well in stride with the college books, and one wonders what our textbooks will be like twenty-five years hence. Kendall[4] has summarized the situation very well in his statement that

"Few teachers of the standard inorganic texts find their classes able to cover the whole of the material contained in a satisfactory way. Additions are continually being made to the subject matter, the number of pages increases considerably with each revision, yet the capacity of the normal brain remains constant and the academic year is fixed at 32 weeks."

The chemistry of titanium is a good illustration of new material that appears likely to be added to our chemistry textbooks. Of eighteen metals listed in the order of their abundance in the earth's crust, titanium stands second and its compounds are becoming increasingly important in pigments, alloys, ceramics, paper, leather, and textile processing, etc. In a recent article on titanium by McKinney and Madson,[5] the authors make the following statement.

"About one hundred tons of titanium oxide pigments are being produced daily, and the business involved amounts to millions of dollars a year. Surely the technical importance and the great abundance of the element merit greater consideration by the chemists of the world. We are looking forward to the time when all books on general chemistry will contain a chapter devoted exclusively to titanium."

Our second factor, the increase of about forty per cent. in enrolment of high-school pupils in thirty years, has a definite influence upon our science teaching. A greater emphasis upon the so-called applied science, and upon demonstration work rather than individual laboratory work are due, in part, to this factor. It is a familiar fact that in many communities it has been found difficult to provide space and facilities for the ever-increasing number of boys and girls crowding into the high schools. With defaults in financial support from taxes during the depression, this has been a matter of grave concern.

Our third factor, profound changes in our social and economic life, such as loss of employment, change in place and scale of living, has changed the viewpoint and the interests of many parents and boys and girls. Demand for new vocational courses on the one hand, and a lack of confidence in the social value of the whole program of science instruction,[6] on the other hand, are traceable to this third factor.

Having reviewed these three social factors, let us now consider the two important questions, what shall we teach, and how shall we teach it? We naturally turn to the various syllabus outlines available because they represent the experience of the past and because they afford a working basis for our future efforts.

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* An address given at a meeting of the Northeastern District of the Pennsylvania State Education Association (Science Section), Sunbury, Pennsylvania, April 17, 1937.

[1] BEAUCHAMP, WILBUR L., "Instruction in Science." Bulletin 1932 (No. 17), National Survey of Secondary Education.

[2] POND, G. G., "Chemistry, Parts I and II," 1909.

[3] DEMING, H. G., "General chemistry," John Wiley and Sons, Inc., New York City, 1935.

[4] KENDALL, JAMES, "Preface to the First Edition" of "General chemistry," Appleton-Century Company, New York City, 1936.

[5] MCKINNEY, ROBERT M. AND WILLARD H. MADSON, "Titanium and its more useful compounds," J. CHEM. EDUC. 13, 155 (1936).

[6] TIDSLEY, JOHN, "Science teaching seen losing force." Address before the Science Council, Hotel Biltmore, New York City, *New York Times*, February 7, 1937.

We are accustomed to think of our courses as general science, biology, physics and chemistry, rather than first-year science, second-year science or tenth-grade science, eleventh-grade science, etc. Beauchamp makes the following statement in this connection.[7]

"The lack of a general viewpoint toward the teaching of science is usually exhibited in courses formulated by subject matter specialists; the content of the course is dictated solely by the logical divisions of the subject. Neither the contributions of the subject to the general aims of education nor the psychological and pedagogical considerations are taken into account in determining the organization or subject matter selected."

The foregoing statement deserves some comment. In the first place, it is natural that our courses should be formulated by "subject matter specialists" because they are in position to provide the necessary sound body of facts and principles. The writer is of the opinion that logical and scientific divisions of subject matter may in many cases be pedagogical as well. A specific illustration will emphasize this point. The Pennsylvania state syllabus[8] for chemistry and the revised outline of high-school chemistry prepared by the committee of the Division of Chemical Education of the American Chemical Society[9] include water as the first topic to be studied, because water is our most common substance and is indispensable to all animal and vegetable life. It is a liquid and is therefore more tangible to the pupil than a gas such as oxygen. A study of distillation, filtration, and aeration as means for rendering "raw" waters suitable for use, and the effects of mineral matter in water in laundering, in storage batteries, and in boilers, also harmful bacteria, can be discussed in a general way. Definite formulas of mineral salts such as calcium bicarbonate, alum, are not necessary at this point. The mere mention of these substances naturally creates a desire to know more about their nature and composition. Properties of water such as its three physical forms and the reversible nature of the changes

$$\text{Ice} \rightleftarrows \text{Water} \rightleftarrows \text{Steam}$$

lay a foundation for the study of reversible chemical changes. The fact that heat is absorbed in carrying out this change from left to right brings the energy factor into the picture and the energy or heat effects should be emphasized qualitatively later on in the reversible chemical changes, such as

$$\text{Water} \rightleftarrows \text{Hydrogen} + \text{Oxygen}$$
$$\text{Mercuric oxide} \rightleftarrows \text{Mercury} + \text{Oxygen}$$

Another illustration of the energy relation is the photosynthesis of starch from carbon dioxide and water with liberation of oxygen and the reverse reaction in which the carbohydrate is oxidized to carbon dioxide and water with the liberation of the heat energy absorbed from sunlight. This reaction also illustrates the interrelations of physics, chemistry, and biology. The energy relations deserve a greater emphasis than they now receive and will undoubtedly be given a more prominent place in the future.[10,11]

Further study of water includes effects of temperature change upon solubility of solids such as salt, saltpeter as well as air in water, types of solutions and crystallization of solids from solution. The examination of the water content of alum, blue vitriol, and Epsom salts may be taken up at this point. Finally, the composition of water as shown by an actual demonstration of electrolysis leads naturally to the study of oxygen and hydrogen.

Some teachers may object to this plan on the grounds that a study of the impurities and purification of water requires a knowledge of formulas. This objection applies also to the traditional plan of beginning the course with a study of oxygen. Substances such as potassium chlorate and mercuric oxide are used which at first are merely named and their formulas are often presented a little later after formula and equation writing have been considered.

In the attempts to arrange the subject matter of chemistry in a "pedagogical order," however, there is the possibility of doing violence to the natural or scientific interrelations of the subject matter, and thus adding to the difficulties of the student. In the speaker's opinion, both the Pennsylvania syllabus and the A. C. S. syllabus in chemistry are open to this criticism. These outlines contain many very helpful suggestions, and teachers are urged to make use of them as far as possible. Constructive criticism will be welcomed, of course, by the committees in charge of the preparation of these outlines. In concluding this part of the discussion, one practical suggestion is proposed. Teachers, and especially inexperienced teachers, who desire a practical working syllabus of chemistry and physics, will find the New York State syllabus very useful.[12] It contains a minimum body of subject matter arranged in such a way that it may be used effectively with the standard textbooks. It was first published in 1916 and, with subsequent revision, it represents the organized experience of many teachers and is used extensively in the public high schools in New York State.

It is not my purpose to make any detailed comment upon the syllabus outlines in physics and biology and general science because my experience is so limited in these fields. The organization of the courses in biology and physics may, however, be considered briefly.

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[7] BEAUCHAMP, *loc. cit.*, p. 6.

[8] "Course of study in science for senior high schools," p. 85, Bulletin 74, Department of Public Instruction, Harrisburg, Pa., 1932.

[9] "An outline of essentials for a year of high-school chemistry," J. CHEM. EDUC., **13**, 175 (1936).

[10] BAKER, R. A., "Some trends in chemical education." Address before The New England Association of Chemistry Teachers.

[11] SCHLESINGER, H. I., "General chemistry," 3rd Edition, Longmans, Green and Co., New York City, 1936.

[12] "Syllabus in physics and chemistry," The University of the State of New York Press, Albany, N. Y., 1936.

"Organization around different plants and animals, emphasizes the dissimilarities of living things; organization around life processes and activities emphasized the similarity of living things. It is, of course, possible to arrive at an understanding of biological principles by either method. There is no evidence to indicate that one method of organization is superior to the others. The two viewpoints are included in the report because they represent a fundamental difference in the attack upon biology. Recent opinion as indicated by the New York State syllabus and the report of the committee in the Thirty-first Year Book of the National Society for the Study of Education tends to support the latter viewpoint.[13]

"Physics, of course, is a relatively old subject as compared with general science, biology, and chemistry. Blake's "Natural Philosophy," published in 1835, shows approximately the same organization as the physics textbooks of today, with the exception that astronomy, then included in the course, has become a separate field of instruction. It may be that the final word on the organization of a course in physics has been said. On the other hand, the decline in the enrollment in the subject at least suggests that a reorganization with a change of emphasis might be desirable."[14]

A decrease in emphasis upon the more abstract mathematical phases of high-school physics and more emphasis upon the practical applications in sound and electricity, for example, may be evidences of the tendency to meet this need for reorganization.

Peterson[15] has recently suggested a "fusion" of physics and chemistry and proposes twenty practical topics such as air-conditioning, the motor car and the railroads, the petroleum industry, etc. This plan is apparently an extension of the concept upon which our general science courses are based. It may be regarded as a step in the direction toward a unified science program. At least one school in Pennsylvania is working on such a program. We need to proceed very carefully in this field; otherwise we may have to face the criticism that our instruction is too superficial.

The literature of our profession contains a vast amount of material dealing with the problems of objectives. Apparently, we are beginning to understand better why we are teaching the various subjects in the curriculum and are now better able to set definite objectives, *e. g.*, in the sciences. Let me suggest two objectives which I believe are sound and applicable in general college chemistry, in high-school chemistry, physics, and general science. These objectives are (1) to help the pupil to understand and to appreciate his or her environment and (2) to teach the pupil to see, to think, and to do. The science teacher should keep these objectives clearly in mind in dealing both with pupils who expect to enter college and those who do not. Success in life in whatever field one happens to be depends in large measure upon the ability to understand one's environment and upon the ability to see and to think and to do. The various other objectives such as the so-called scientific method, scientific attitude, etc., are implicit in our second objective. If one is trained in the processes of careful observation, in habits of thinking about what has been observed, he must have acquired the scientific attitude and method of approach which is useful both to the layman and the scientist. During the past ten years, it has been my privilege to teach chemistry to nurses in a nearby hospital. At commencement, prizes are given to the graduates for special attainments in both academic work, including chemistry, psychology, bacteriology, pharmacology, etc., and in practical nursing work. It happens frequently that the individuals who rank high in academic work also rank high in practical work. The intelligence of the individual probably has much to do with this matter, as well as the question of scientific training.

Let us now consider some recent trends in teaching methods.[16]

1. Courses tend to be organized more around major ideas or concepts based upon certain general principles of science or upon life situations. These major ideas are known as units, or as problems and projects.
2. Less emphasis is placed upon quantitative aspects and more emphasis is placed upon the qualitative aspects of the work in physics and chemistry. Greater attention is also given to a study of the environment.
3. Greater use is made of newspapers, magazines, and bulletins.
4. Supervised study has supplanted oral recitations to quite an extent.
5. Increased use of mimeographed guide sheets and work books has resulted in greater emphasis being placed upon pupil activity and less emphasis upon teacher activity.
6. More demonstration work and less individual experimental work appears to be done especially in general science and to an increasing extent in physics and chemistry.
7. There is greater correlation now between the experimental work and the textbook and related study in the classroom. This has been brought about by increased emphasis upon the study of projects and the solution of practical problems based upon data obtained from the experimental work and the textbook or other references. This tendency has also resulted in a decreased emphasis upon formal records of laboratory work.
8. Greater use is being made of unusual aids including both lantern slides and motion picture films. This practice is commendable up to certain limits.

In referring to the increasing use of the demonstration method, I wish to present two statements from an address by W. W. Knox, State Supervisor of Science, Albany, New York, given at the New York meeting of the American Chemical Society in April, 1935.[16]

"It is evident that the experimental data we possess point definitely to the superiority of the demonstration method as far as those outcomes that may be measured by the ordinary written tests are concerned. The studies referred to do not furnish us with a satisfactory solution of our problem. A measuring instrument must be devised for determining the educational product

[13] BEAUCHAMP, *loc. cit.*, p. 35.
[14] BEAUCHAMP, *loc. cit.*, p. 35.
[15] PETESRON, S. A., *Sch. Sci. & Math.*, **37**, 449 (1937).
[15] BEAUCHAMP, *loc. cit.*, p. 62.
[16] KNOX, W. W., "The demonstration method of teaching chemistry," J. CHEM. EDUC., **13**, 166 (1936).

unobtainable without the laboratory method. Indeed, we are not certain what procedure should constitute either the laboratory method or the demonstration method. I seriously doubt the wisdom of standardizing to any great extent either method. Teachers vary greatly in their ability to perform experiments or to conduct laboratory periods. Pupil needs also vary. Perhaps laboratory work should not be required of all pupils. The life-motivating influences may ultimately decide the issue for secondary-school work. The question might well be raised, which method stimulates maximum pupil interest?"

". . . .In the advanced sciences, physics, chemistry and biology, it has been possible to maintain a relatively high standard of individual laboratory work in spite of some administrative pressure to the contrary. In New York State, laboratory work is required in the advanced sciences. In my opinion there is no danger of modification of these requirements in the near future. I am convinced that the abandonment of the laboratory method at the present time would mean a degeneration of science teaching in the secondary schools."

Simons[17] has given us a very definite view of the function and the value of laboratory work.

"Our best teaching is done in the laboratory, for here the student and teacher come in intimate contact; and the student is kept actively at work mentally and physically under the guidance of the teacher. It is here where we accomplish what some of our greater universities are attempting in their tutorial systems. For training purposes it gives us our best opportunities. As it develops a realistic familiarity with substances by intimate contact, it produces a sounder appreciation of them than lecture or textbook material. It is this appreciation which is of such great cultural value. In modern chemistry courses the laboratory is not conducted by giving the student recipes for his work, which he follows blindly. Selected problems are given, which require the student to think about what he is doing and how he is doing it. Frequently, he is guided by means of a set of questions. What could be a more ideal way of teaching?"

In conclusion, we may say that the successful science teacher is one who possesses the capacity and the desire to learn and to help young people learn more of the truths of nature. For such a one the true measure of success can be expressed in the words of the immortal Faraday.

"I have never yet seen a boy who was not able to understand by simple explanation, and to appreciate the point of an experiment."

[17] SIMONS, J. H., "Teaching chemistry for its cultural and training values," *Science*, **84**, 408 (1936).

The 1936–1937 COLLEGE CHEMISTRY TESTING PROGRAM*

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THIS second annual report of this Committee on the testing program in general chemistry marks the first year in which the tests have been given under the direct sponsorship of the Division of Chemical Education. During the past seven years, the Coöperative Test Service of the American Council on Education, under the supervision of Dr. Ben D. Wood, has been at work on the general problem of the construction, distribution, and use of better tests at the high-school and college levels. In the chemistry field this project has centered on the determination of the desired outcomes of instruction in chemistry, and the construction of adequate means of measuring those outcomes.

In previous years, three different tests have been available, with resulting difficulty in tabulation of data.[1] This year, more advertising of the tests was undertaken, and a greatly increased circulation achieved for a single form of the test, designed to measure the following fields.†

Part 1. Chemical Theory, Occurrence, Commercial Preparation, and Properties.
Part 2. Vocabulary.
Part 3. Familiarity with Symbols and Formulas.
Part 4. Numerical Problems.
Part 5. Balancing Chemical Equations.
Part 6. Valence of Elements and Radicals.
Part 7. Application of Principles.

Table 1 shows the distribution of total scores. Scores on the individual parts varied from a maximum of 7 points for Part 6 to 58 points for Part 1. A con-

* Presented before the Division of Chemical Education at the ninety-fourth meeting of the A. C. S., Rochester, N. Y., September 6, 1937.

[1] "The 1935–36 college chemistry testing program," J. CHEM. EDUC., **14**, 229–31 (1937).

† Tests may be obtained from the Coöperative Test Service, 437 West 59th Street, New York City.

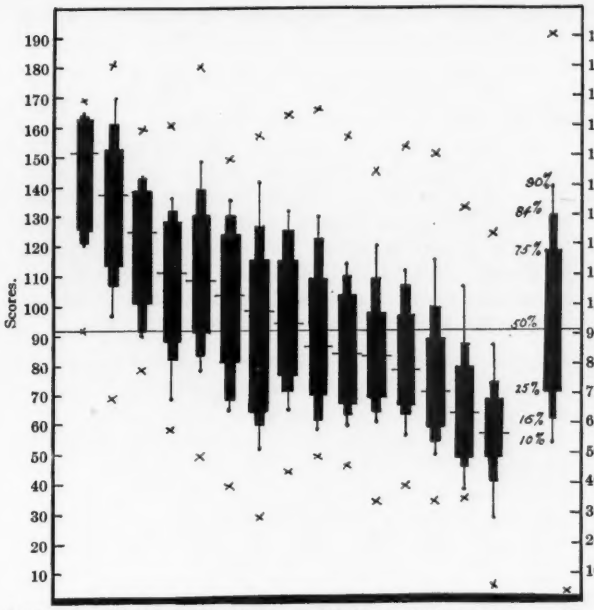

FIGURE 1.—VARIABILITY OF ACHIEVEMENT AS MEASURED BY TOTAL SCORES

The middle horizontal line represents the national median. Each of the bars represents an individual college. The wide portion of each bar represents the range of scores of the middle half in each college. The narrow parts extend to the 16th and 84th percentiles in each college, *i. e.*, one standard deviation above and below the mean. The lines at the ends extend down to the 10th percentile and up to the 90th percentile. The crosses below the bars represent the lowest scores, and those above, the highest scores in the several colleges (the range). The short cross line at the middle of each bar represents the median score of the college.

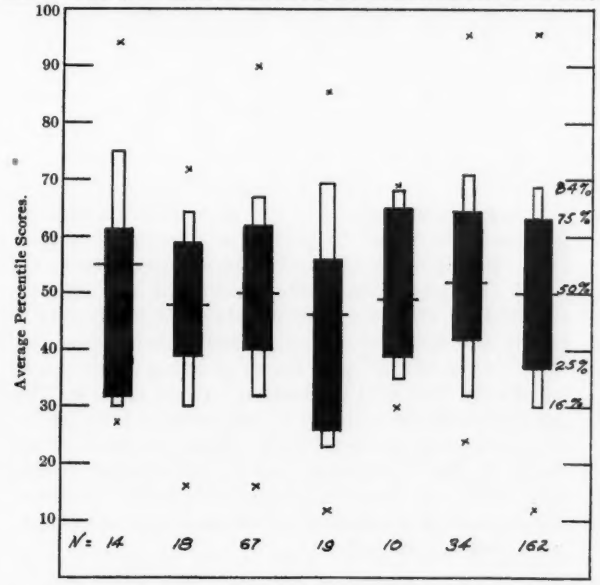

FIGURE 2.—VARIABILITY OF ACHIEVEMENT BY DIFFERENT TYPES OF COLLEGES

Each bar represents the colleges of one type. The wide, dark portion of each bar represents the range of average percentile scores of the middle half in each group. The narrow parts extend to the 16th and 84th percentiles in each group. The crosses below the bars represent the lowest average scores, and those above, the highest average scores within each group. The short cross line at the middle of each bar represents the median score of each group.

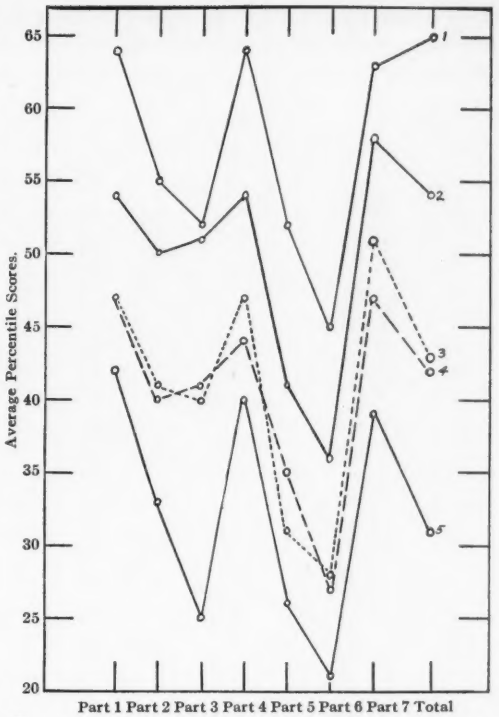

FIGURE 3.—VARIABILITY AMONG DIFFERENT VOCATIONAL GROUPS

1. Engineering, 2715 cases
2. Medicine, 1864 cases
3. Teaching, 1076 cases
4. Business, 510 cases
5. Agriculture, 439 cases

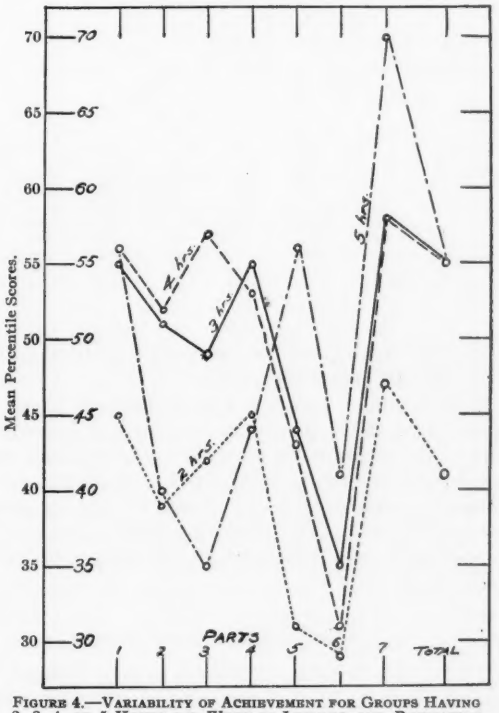

FIGURE 4.—VARIABILITY OF ACHIEVEMENT FOR GROUPS HAVING 2, 3, 4, OR 5 HOURS PER WEEK IN LECTURE AND RECITATION

densed distribution table is given in Table 2 with the scores on each part arbitrarily divided into eight equal intervals.

TABLE 1

DISTRIBUTION OF SCORES

Score	*Frequency*
187–191	1
182–186	6
177–181	13
172–176	29
167–171	43
162–166	66
157–161	113
152–156	119
147–151	158
142–146	217
137–141	226
132–136	274
127–131	289
122–126	349
117–121	364
112–116	382
107–111	402
102–106	458
97–101	512
92– 96	502
87– 91	548
82– 86	559
77– 81	583
72– 76	551
67– 71	467
62– 66	500
57– 61	428
52– 56	338
47– 51	299
42– 46	234
37– 41	181
32– 36	121
27– 31	73
22– 26	56
17– 21	22
12– 16	14
7– 11	6
2– 6	1
	9504

TABLE 2

DISTRIBUTION OF PART SCORES

Scores	*Frequencies*						
	Part 1	*Part 2*	*Part 3*	*Part 4*	*Part 5*	*Part 6*	*Part 7*
Highest	27	381	1085	856	4112	3891	19
	198	770	2479	875	1089	2645	158
	517	2515	2636	1193	2005	1140	425
	1013	2542	1840	1359	855	564	767
	1681	1979	935	1437	662	337	1353
	2686	954	364	2033	421	294	1673
	2439	301	137	1306	203	251	1749
Lowest	943	62	28	445	157	382	3360

In Table 3 are given the national percentiles, derived from the 9504 papers reported.

Each score in each column of Table 3 shows the upper limit of the percentile indicated at the edge of table. For example, one per cent. of all students made total scores of 29 or less; fifty per cent. made scores of 92 or less; all scores between 93 and 102 have percentile values of 50+ to 60. From this table, therefore, the relative rank of any student among his fellows can be determined.

VARIABILITY OF ACHIEVEMENT

There are striking differences among colleges and among students in the same and in different institutions. This is shown graphically in Figure 1, which shows the distribution of scores of fifteen representative institutions ranging from that with the highest to that with the lowest median score. Identity of these institutions is not known to this Committee.

It will be noted, for example, that the poorest student in college 183 equaled the national median, while ninety per cent. of the students in school 169 were considerably below the national median. It will be noted that the group at school 183 is quite homogeneous, with only a small vertical spread, while college 120 shows the opposite extreme, the poorest student having a percentile score of 1, and the best of 97.

TABLE 3

	Part 1	*Part 2*	*Part 3*	*Part 4*	*Part 5*	*Part 6*	*Part 7*	*Total Score*	
No. of Colleges	162	162	162	162	162	162	162	162	
No. of Cases	9504	9504	9504	9504	9504	9504	9504	9504	
Mean	20.6	13.0	11.3	17.0	17.4	5.6	10.1	94.9	
Sigma	10.8	4.0	2.8	9.9	5.3	1.9	8.1	32.6	
Percentile									*Percentiles*
100	58	21	16	35	22	7	38	191	100
98	45	20	16	35	22	7	29	163	98
93	38	19	15	34	22	7	24	147	93
90	36	18	15	32	22	7	22	140	90
84	32	17	14	29	22	7	19	130	84
80	30	16	14	27	22	7	17	125	80
75	28	16	13	25	22	7	16	118	75
70	26	15	13	23	22	7	14	112	70
60	22	14	12	19	21	7	11	102	60
50	19	13	12	16	18	6	9	92	50
40	17	12	11	13	17	6	7	84	40
30	14	11	10	10	16	5	4	76	30
25	13	10	10	9	15	5	3	71	25
20	11	10	9	8	13	5	2	61	20
16	10	9	9	7	12	4	1	62	16
10	8	8	8	4	9	3	1	54	10
7	6	7	7	3	8	2	0	49	7
3	3	5	5	1	4	0	0	39	3
1	1	3	4	0	0	0	0	29	1

It must be emphasized at this point that the purpose of this report is not to praise those institutions that show up well, not to criticize those with poor showings. Dr. F. E. Brown has wisely condemned any attempt to mold all students into one standard form to fit a rigidly standardized course. What is being done, instead, is the setting up of norms of actual achievement by several thousand students on a test covering the core material agreed on by a large group of instructors. Any college using this test can compare its results with those of other institutions and decide whether, in the light of its own aims, equipment, and caliber of entering student, it is teaching the fundamentals of chemistry as well as it should.

TYPES OF COLLEGES

A study was made of the results obtained at six different types of institution. In Figure 2 is shown the distribution of the average grades at each school on the whole examination. Any institution, by referring its average scores to this graph, may identify its relative position in its own group.

PROFESSIONAL GOALS

In Figure 3 are plotted the average percentile ratings for the five most popular professional groups. Care must, of course, be taken in interpreting this. It does not necessarily mean that a future farmer can be expected to do much poorer in chemistry than a prospective engineer. All that can be said is that as a result of all the factors of training, interest, experience, and heredity, the average engineering student does better in freshman chemistry than any other, and so on.

TIME DEVOTED TO LECTURE AND RECITATION

Figure 4 shows graphically the average percentile scores of students who devoted 2, 3, 4, and 5 hours per week, respectively, to lecture and recitation. The results are interesting both on the part scores and on the whole examination. It is evident that time spent in class is not the most important factor in determining how much chemistry a student will learn. The burden of proof seems to be on those who demand five hours per week.

SIZE OF CLASS

Table 4 shows the distribution of college averages by size of group tested. Since this latter is not necessarily coincidental with the size of the class, this table cannot be used to settle the problem of large versus small classes. It will serve to demonstrate that the few very large groups included did not unbalance the national distribution.

TABLE 4

COLLEGE AVERAGES DISTRIBUTED BY SIZE OF GROUP TESTED

Percentiles *Score*	1–29	30–99	100–199	200–529	530	*Totals*
96–97	1					1
94–95	1					1
92–93	1					1
88–91	1					1
84–87	2	1	1			4
79–83	2		2			4
72–78	3		5			8
66–71	6	5	1	1	1	14
58–65	12	8	3			23
50–57	11	12	1	2		26
42–49	12	17	2			31
34–41	6	4	2	1		13
27–33	7	10	1		1	19
21–26	5	5				10
16–20	1	2	1			4
12–15		2				2
N	70	72	14	4	2	162

PREVIOUS TRAINING IN CHEMISTRY

Table 5 shows again what has been found frequently —that those who have had chemistry in high school do better than those who have not.

MEN VS. WOMEN

Table 6 shows that 6518 men averaged noticeably better than 2485 women. Again, as in the other tables, it must be emphasized that these are not controlled experiments in which one group is balanced against another with all variables constant except the one under consideration.

TABLE 5

EFFECT OF HIGH-SCHOOL CHEMISTRY

	Averages			
	Raw Scores		*Percentiles*	
Part	Without High-school Chemistry	With Chemistry	Without High-school	With Chemistry
1	18	22	44	61
2	12	14	39	54
3	10	12	32	56
4	14	19	46	59
5	16	18	30	49
6	5	6	26	43
7	8	11	47	62
Total	83	102	40	61
No. of cases	3670	5834		

TABLE 6

MEN VS. WOMEN

	Averages			
	Raw Scores		*Percentiles*	
Part	Men	Women	Men	Women
1	22	17	58	42
2	13	12	51	38
3	12	11	49	35
4	18	14	57	43
5	18	17	46	33
6	6	5	36	28
7	11	8	59	48
Total	99	83	57	39

VALIDITY AND DIFFICULTY

One of the most vexing problems in test construction is the difficulty of making it capable of distinguishing the good from the poor student, and of keeping successive editions at the same level of difficulty. For a representative sample of papers, an item analysis was carried out to determine how well these problems had been met. The difficulty of an item is measured by the percentage of correct responses to that item. Obviously, an item answered correctly by every student is merely filling up space without helping to rank students. The validity is expressed in terms of validity indices,[2] determined in the following manner. It is assumed that the students who get high scores have a better understanding of the subject, as measured by the test, than those who get low scores. For each item, the percentage of right answers of the high-scoring group is plotted against the percentage of right answers by the low-scoring group. The 45° diagonal of the graph, therefore, represents no discrimination, an item answered correctly by exactly the same percentage of good and poor students. This diagonal is given a value of zero, and the amount of deviation of each item from the diagonal determines its validity index, expressed numerically in quarter-sigma units. An index of 2 is considered satisfactory, one of four or better indicates very good discriminatory power, while a minus value indicates that poor students answered the item correctly more often than good students.

[2] "The 1933–1934 College Physics Testing Program," *The American Physics Teacher*, **2**, 134 (1934).

Tables 7 and 8 show that, thanks to careful sifting by the authors of this test, it is made up of items of high validity, and with an excellent distribution of difficulty. Ideally, the number of items at each level of difficulty should be the same, so that the sampling may be as adequate as possible for a wide range of student ability. This test is slightly weak at the extremes, but is still satisfactory.

TABLE 7

DIFFICULTY OF INDIVIDUAL ITEMS

Number of Items

Percentage of Correct Responses	Parts 1	2	3	4	5	6	7	Total
95		1	3		3			7
90			2		5			7
85		5			6	4		15
80	1	3	2	1	3			10
75	7	1	1	1	1	2	1	14
70	6	2			1		3	12
65	4	3	1		2	1	1	12
60	7		2		1		3	13
55	5	1	1				3	10
50	8	2	1				4	15
45	4			2			6	12
40	4	1		1			6	12
35	9	1	1	2			6	19
30	2		2				1	5
25	3	1					2	6
20	1						1	2
15							2	2
N	61	21	16	7	22	7	39	173

TABLE 8

DISTRIBUTION OF VALIDITY INDICES

Number of Items

Validity	Part 1	2	3	4	5	6	7	Total
10				2				2
9			1	2			1	4
8	1		1	1				3
7	1	1				3	4	9
6	10	2	5	1	8	2	5	33
5	9	4	1	1	5	1	13	34
4	17	4	1		5	1	7	35
3	14	5	2		3		6	30
2	6	4			1		3	14
1	3	1	4					8
0			1					1
N	61	21	16	7	22	7	39	173

Table 8 shows that all except nine items possessed satisfactory discriminatory power; a great number had very high validity indices, while none had negative values.

CONCLUSIONS

This year, 21,645 chemistry tests were distributed to two hundred ninety colleges. One hundred sixty-two of those institutions reported their results to the Coöperative Test Service, and the data included in this paper cover the 9504 tests thus reported. Norms are included, so that any paper, or any part of any paper can be compared with the national averages. The fact that such a large number of tests was used signifies that there has been a fair amount of agreement on core materials for elementary courses, and that extent of learning measured relatively can be of practical value to teachers.

To a limited extent, and even to that extent to be used with caution, these results can be used to indicate differences between achievements (1) at different schools, (2) at institutions of different types, (3) by different vocational groups, (4) with varying numbers of hours devoted to lecture and recitation, (5) with or without high-school chemistry (6) by men and by women.

To the extent that a test covering Chemical Theory, Occurrence, Commercial Preparation and Properties, Vocabulary, Symbols and Formulas, Numerical Problems, Balancing Chemical Equations, Valence of Elements and Radicals, and Application of Principles measures the desired outcomes of a course in general chemistry, the data included herein can be used by any teacher of chemistry to determine the effectiveness of his teaching. This, of course, would be more nearly valid were comparable forms given before and after teaching.

Complaint has been made that this test includes too much emphasis on factual material and too little on thinking. Such objection assumes that teachers can create, or at least train, thinkers. Wood and Beers[3] dispute this, saying, "But the attempt to make all or any considerable fraction of the population . . *.thinkers* is at least anomalous in view of the obvious fact that it has been and is impossible, by any teaching or coercive methods thus discovered, to make them *knowers*, even of a mediocre sort . . . . Thinking can have no real existence apart from knowledge. Perhaps the best, if not the only, way to promote fruitful thinking is to promote knowledge and a deeply set respect for facts . . . . . Information and knowledge are at least partly within the control of teaching, and thinking and thinking ability are certainly much less, if at all, under the control of teaching, except as thinking can be determined in quality and range by knowledge."

In 1934–35, 8145 tests were distributed; in 1935–36, 12,380; and this year, 21,645. This is very gratifying progress. This Committee again wishes to thank each department and each teacher who collaborated in this program. Without the assistance of many hands in making the experimental studies necessary, in editing the questions, and in accumulating the necessary data, this program would have been valueless.

Thanks are also due in abundance to the Coöperative Test Service and Dr. Ben D. Wood's staff of assistants, who made the numerous statistical studies requested for use in this report.

It is hoped that next year an even greater percentage of those using these tests will report their results. Only thus can completely valid norms be derived.

The Committee on Examinations and Tests, Division of Chemical Education

B. CLIFFORD HENDRICKS — R. E. KIRK
EARL W. PHELAN — S. R. POWERS
RUFUS D. REED — FRANK B. WADE
O. M. SMITH, *Chairman*

[3] WOOD, B. D. AND F. S. BEERS, "Knowledge versus thinking?" *Teachers' College Record*, **37**, 487 (1936).

SURFACE TENSION *by* MAXIMUM BUBBLE PRESSURE

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THE determination of surface tension by the method of maximum bubble pressure is an excellent experiment for the undergraduate physical chemistry laboratory. The apparatus, with the exception of the glass bubbler, which is not expensive, can be assembled from materials found in the laboratory and shop. An inexpensive substitute obviates the need of a cathetometer, as in the capillary height method. Surface tension measurements of different liquids can be made rapidly and accurately, and, if desired, the student can carry out the experiments at a series of temperatures with greater facility than with the capillary height

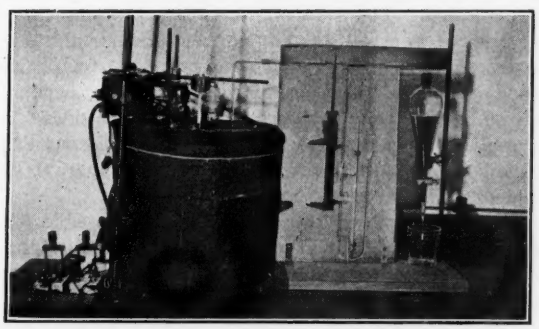

FIGURE 1.—THE COMPLETE APPARATUS

method. From this series of values the temperature equation can be derived by least squares, the critical temperature determined, and Eötvös' constant calculated.

Cantor (*2*) and Jaeger (*5*, *6*) originally devised and developed this method so that satisfactory determinations were possible. An air bubble was blown at the bottom of a tube dipping into a liquid and the pressure required to burst the bubble measured. Sugden (*8*, *9*) improved and extended the method, avoiding many of the experimental difficulties by using two tubes of different diameter dipping to the same depth in the liquid. An empirical equation,

$$ST = A\,(P_1 - P_2)\left(1 + 0.69\,r\,\frac{gD}{P_1 - P_2}\right) \qquad (1)$$

in which A is a calibration constant, $P_1 - P_2$ is the measured pressure difference in dynes / sq. cm., r is the radius of the larger tube, and D is the density of the liquid being measured proves satisfactory under the proper conditions. A more complete discussion of the theory is given by Adam (*1*).

The apparatus, which is shown in Figure 1, consists essentially of a glass bubbler suspended in a constant temperature bath, a manometer, and a mercury aspirator.

The bubbler, Figure 2, can be purchased directly from Scientific Supplies, Ltd., of London, or it can be made by a competent glass-blower. The size varies with the dimensions of the other apparatus available; 15–25 cm. overall length is convenient. The two sections of the instrument are joined by a ground-glass connection (*a*); the side-arm (*b*) is connected with the manometer and aspirator system; and (*c*) and (*d*) are the wide and narrow tubes, respectively. The narrow tube (*d*), which is of capillary dimensions, is made separately and tested before being joined to the tube (*e*). The di-

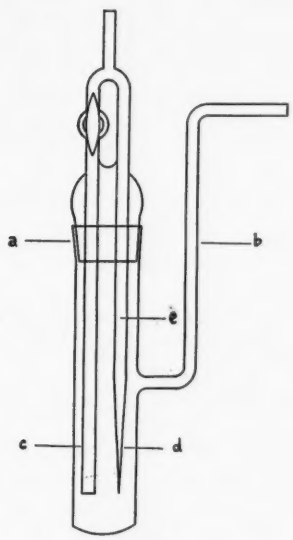

FIGURE 2

ameter of this capillary should be such that it gives a pressure difference of 4–10 cm. of ethyl alcohol on the manometer when air is sucked through the tip, which is dipped into benzene to a depth of about 1 cm. The

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appropriate capillary is joined to (*e*) so that it and the wide tube (*c*) end in the same horizontal plane.

The open manometer consists of a U-shaped tube of $^1/_2$–1 mm. internal diameter Pyrex tubing, which is connected to the aspirator and bubbler. As a cathetometer is often not available in the laboratory a simple and efficient substitute can be constructed by mounting a vernier caliper on small metal blocks in such fashion that the knife edges used for measuring internal diameter come directly over the manometer tube. The height of the meniscus can then be measured directly to 0.01 cm., with further estimation possible.

The mercury aspirator recommended by Sugden is constructed by drawing out the tube of a 250-ml. separatory funnel to a fine capillary, the diameter of which should be such as to cause bubbles to form at the rate of one per second on the bubbler tubes. The manometer, caliper, and aspirator are mounted on a wooden support, with the glass tubing supported by wires passing through holes in the support.

The bubbler is placed in the laboratory constant temperature bath, or, if measurements at more than one temperature are desired, a simple temperature bath with control to at least 0.1°C. can be constructed from a double-walled container, such as an old calorimeter tank, with a motor stirrer mounted on a separate support to reduce vibration. An immersion heater and a light bulb are operated manually and serve to heat and control the temperature. A 100°C. × $^1/_{10}$ thermometer is used. An excellent extension rod for mounting the bubbler or thermometer can be made by screwing a tripod leg into the socket left when the adjustable portion and jaws of a single buret clamp are removed.

The instrument constant, A, is determined by measurement of pure, fractionated benzene, the surface tension of which is given by the equation

$$ST = 70.26\left(1 - \frac{T°K.}{560}\right)^{1.20} \qquad (2)$$

and substitution of the suitable values in equation (1). The density of benzene at various temperatures can be found in the *Critical Tables* (*4*).

The density of the manometer alcohol, which is tinted with fuchsine, is determined at a few temperatures between 20° and 30°C. and a graph or table constructed for intermediate temperatures. The pressure difference in cm. of alcohol is converted to dynes/sq. cm. As bubbles are formed on the large tube, the stopcock of which is open, there is an increase in pressure and then a sudden decrease as the bubble bursts. The reading is taken at the lowest pressure, after which the stopcock is closed and the pressure of the bubbles formed on the small tube taken.

The density-temperature equation for various liquids to be tested can usually be found in the literature or can be determined for a range of temperature as a subsidiary experiment. The parachor of the compound can be determined after measurement and compared with known values, and the critical temperature and the constant can be calculated from data at two different temperatures by means of the Ramsay and Shields' modification (*7*) of the Eötvös equation (*3*).

Benzonitrile, methyl ethyl ketone, benzyl alcohol, butyl chloroacetate, ethyleneglycol monoethyl ether, and *m*-iodotoluene were measured with the apparatus as described. The following liquids are recommended for original work on the part of the student: anisaldehyde, chloroacetone, *o*-dichlorobenzene, α-naphthyl isocyanate, *tert.*-butyl bromide, ethylaniline, eugenol, heptaldehyde, isopropyl bromide, *n*-propyl iodide, *n*-propyl *n*-proprionate, *o*-chlorophenol, *m*-chloroaniline, *p*-cymene, *o*-iodotoluene, *o*-iodoanisole, methyl *p*-toluene sulfonate, and terpineol.

As an example of the determinations possible, the measurement of benzyl alcohol may be considered. From 25–35°C. the values of the surface tension give the approximate equation, $ST = 44.593 - 0.1268t$; a parachor of 263.3 as compared with the known value of 266.1; a critical temperature of 455°C.; and a constant, k, of 2.15.

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(6) JAEGER, *Z. anorg. Chem.*, **101,** 1 (1917).
(7) RAMSAY AND SHIELDS, *Z. physik. Chem.*, **12,** 431 (1893).
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(9) SUGDEN, *ibid.*, **125,** 27 (1925).

DEMONSTRATION EXPERIMENTS USING UNIVERSAL INDICATORS—A CORRECTION

Two minor errors appear in this article, J. CHEM. EDUC., **14,** 274–6 (June, 1937). In the table, "Materials for Yamada's Indicator," on page 275, the amount of bromothymol blue should be 50 mg. instead of 60 mg. On page 276, *Chem. Abstr.*, **23,** 2120 (1929) should be added to Reference 2.

CORRESPONDENCE

COÖPERATIVE OBJECTIVE TESTS IN ORGANIC CHEMISTRY

To the Editor

DEAR SIR:

Most readers of the JOURNAL OF CHEMICAL EDUCATION are doubtless familiar with the work of the Committee on Examinations and Tests of the Division of Chemical Education of the American Chemical Society.

Some may not be aware of the fact that the test in freshman chemistry, which has been developed by this committee over a period of years, was given last spring to about twenty-five thousand students in representative colleges and universities. This in itself is indicative of the success of this project, but doubtless there were other benefits resulting from this undertaking that are not represented by these figures. It is beyond the scope of this note, however, to present arguments for or against the relative merits of objective tests. Rather, we wish to indicate that progress has been and is being made in this general direction.

The latest adventure, in accordance with the action of the Committee on Examinations and Tests at the Rochester meeting, extends the activities of the committee to the development of objective tests in organic chemistry. Since so little work has been done in this particular field, it seems desirable to initiate the project on a coöperative basis so that all who are interested may contribute in some degree to the development of the project.

The present plan calls for a simple beginning whereby it may be possible for instructors of organic chemistry to procure objective tests during the present school year at a nominal cost. These tests, together with the comments received from the various instructors, should serve as a basis for subsequent developments.

The tests, together with the dates that they will be available, are indicated in the following tabulation.

TEST No.	SUBJECT MATTER COVERED	DATE AVAILABLE
1.	Alkanes, alkenes, alkynes, and alkyl halides	Oct. 15, 1937
2.	Alcohols, ethers, aldehydes, and ketones	Oct. 25, 1937
3.	Acids and substituted acids	Nov. 10, 1937
4.	Acid derivatives	Dec. 1, 1937
5.	Carbohydrates (structure, uses, and preparation)	Jan. 5, 1938
6.	First Semester Test (covering above material)	Jan. 15, 1938
7.	Carbohydrates and sulfur compounds	Feb. 1, 1938
8.	Aliphatic nitrogen compounds	Mar. 1, 1938
9.	Foods, metabolism, metallic alkyls, cycloalkanes, benzene, naphthalene, anthracene, and aryl halides	Apr. 1, 1938
10.	Phenols, ethers, aldehydes, ketones, quinones, sulfonic acids, nitro compounds, amines, diazo compounds	May 1, 1938
11.	Heterocyclic compounds, miscellaneous compounds, antiseptics, germicides, dyes, stains, indicators, terpenes, synthetic rubber, and synthetic resins	May 15, 1938
12.	Second Semester Test (covering above material)	May 15, 1938

Each of the regular tests will consist of fifty exercises, and is designed to be answered during a regular fifty-minute period. The semester tests will contain one hundred exercises and will require a two- to three-hour period for their completion.

The regular tests will be delivered, post-paid, at one cent per copy; the semester tests at one and one-half cents per copy. Those interested in this project should advise the writer at an early date as to the number of each of the tests listed above that are desired for this school term.

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THE PERIODIC SYSTEM

To the Editor

DEAR SIR:

Professor Zmaczynski, in his "Periodic System of the Elements" published in the May, 1937, issue of the JOURNAL OF CHEMICAL EDUCATION, has caught an idea for which I had long been groping. There are, however, some points in which I disagree with his arrangement. The enclosed chart will help to make these points clear.

1. Hydrogen occupies all of the first turn of the spiral, except for the last four spaces, which are reserved for helium.

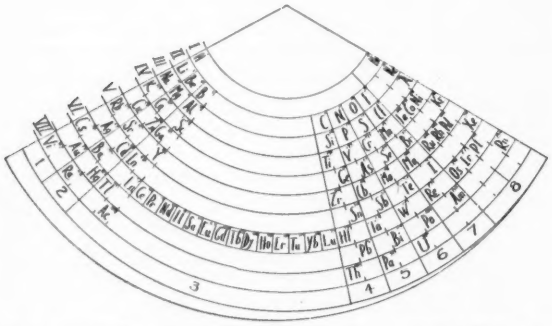
2. Series II and III each occupy a turn of the spiral with each element occupying a double space; except for the Group III elements (B and Al) which hold sixteen spaces each, so that there will be space for the rare earths in the later series; and for the inert gases, each of which holds four spaces for its successors, the metal triads.

3. Series IV and V each require a double turn of the spiral. Each element possesses a double space, which is partially divided, and the element is shifted to the right or left, as in the usual Mendeléeff chart, to establish family relationships. The elements of the metal triads are fitted into the single spaces reserved for them, leaving a vacant space under the inert gases' column.

4. The Sixth Series proceeds like the two preceding ones until we reach the rare earths, the individual elements possessing single compartments. After exhausting this pleiad, we follow the series uneventfully to its end at radon.

5. The unfinished Seventh Series follows the plan of the Fifth, presenting no new features.

This chart represents hydrogen as a sort of prototype element, corresponding to the first seven elements of each of the next two series. Likewise, each of the members of the second and third series is the forerunner of the two sub-families of the succeeding series. For example, lithium and sodium are the primitive members of a family which later subdivides into the copper and potassium sub-family. Since sodium and lithium resemble the potassium more than they do the copper sequence, they are shifted to the left to show this greater likeness. A similar plan is followed for the next six columns. We need only say that, of course, the rare earths belong to the scandium sub-family of Group III.



A PERIODIC SYSTEM OF THE ELEMENTS, AFTER THE PLAN OF PROFESSOR E. W. ZMACZYNSKI

In a somewhat similar manner, helium is represented as the archetypal element which evolves into the two families, the inert gases, and the metal triads.

While this arrangement may not, possibly, account for all the intricacies of atomic structure as well as that of Professor Zmaczynski, it seems to me that it demonstrates the common chemical relations of the elements somewhat better. Due credit is given Professor Zmaczynski for his most ingenious arrangement.

May I repeat the notation made when I presented a previous periodic system; that no such system can represent completely the properties of the elements unless it accounts for every valence form of each element. Such a system I hope to be able to present some day.

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(*Continued from page 554*)

fields of human endeavor and aroused in him an ever-widening interest in problems of the chemical industry. In 1928, he, without relinquishing his posts in Russia, became consultant to the Bayerische Stickstoffwerke. In their laboratory in Berlin he invented and developed a process for the oxidation of phosphorus with water to phosphoric acid—of great interest to the artificial fertilizer industry and I. G. Farbenindustrie.

Already in previous years Ipatieff, like his great inspirer, Dimitri Mendeléeff, had a keen desire to visit the United States of America. This wish was realized in 1930, when Ipatieff visited America and became interested in modern problems of the oil industry. The following year, after his return from Europe, Ipatieff became definitely associated with Northwestern University and the Universal Oil Products Company. Since then he has resided in Chicago and has recently become a citizen of the United States.

In the Laboratories of the Company at Riverside, Illinois, he started several investigations on hydrocarbons, aided by a number of enthusiastic co-workers. It would be premature to discuss these researches[5] at the present time. It may be said, however, that the investigation of the catalytic chemistry of unsaturated hydrocarbons led Ipatieff to a polymerization process which is already employed all over the world in converting millions of cubic feet of cracked gases, heretofore wasted, into valuable gasoline.

For his contributions Ipatieff has received international recognition. He was elected a member of the Russian Academy of Science in St. Petersburg in 1915. He became a member of the Göttingen Academy of Science in 1922, and received the Honorary Doctor's degree of the University of Munich in 1927, and of the University of Strasbourg in 1929. In 1931 he was elected an Honorary Member of the Deutsche Chemische Gesellschaft.

For his achievements in the World War the French Government named him Commander of the Legion of Honor in 1916. The Society of Chemical Industry of France awarded him the Marcellin Berthelot Medal.

Introduced as a young officer to Tzar Alexander III, having frequent personal conferences with Tzar Nicolaus II during the World War, being called back to work by Lenin, and conferring with Trotzky during the years of Revolution, Ipatieff looks back on an experience of seven decades practically unique. However, this is not the place to relate the numerous interesting incidents in the life of Ipatieff.

We would like on this occasion to express the wish of his fellow chemists that the old pioneer, rejuvenated by his contact with America, may work for many more years with his typical energy and enthusiasm for the benefit of his dearly beloved science, chemistry.

[5] A part of them is described in his recent book, "Catalytic reactions at high pressures and temperatures," The Macmillan Company, New York City, 1936.

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ABSTRACTS

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KEEPING UP WITH CHEMISTRY

Radioelements as indicators in chemical and biological research. G. HEVESY AND F. A. PANETH. *Science Progress*, **32**, 38–48 (July, 1937).—Radioactivity is generally regarded as something more or less remote from the interest of practical chemists, who are not specially attracted by descriptions of what is going on in the interior of an atomic nucleus.

Due to the extreme sensitivity of electrometric methods it is possible to detect radioelements in much smaller concentrations than any other chemical substances. Since most radioelements are isotopic with ordinary elements in many investigations it is possible to substitute a radioelement for its inactive isotope. By choosing an appropriate ratio between the quantities of radioelement and inactive element in the sample, it is possible to cover the entire range of mixtures from those detectable only by means of the electroscope to those containing easily weighable amounts of material.

The applications of "radioelements as indicators" fall mainly into three groups; with their aid (*a*) we can study the behavior of minute quantities of a radioelement, or indicated element, down to invisible or unweighable amounts; (*b*) we can determine very small fractions of an indicated substance which has been separated from the main part by solution, diffusion, etc.; and (*c*) by mixing only a fraction of a stable element with its radioactive isotope, we can differentiate this fraction from the rest of the element, and then study the exchange of atoms of identical chemical properties.

One example will suffice to show the use of radioelements as indicators. The solubility of lead chromate at room temperature is too small to be determined with accuracy by gravimetric methods; but with the help of a radioactive indicator we can measure it as readily as we can perform a simple weighing operation. For this purpose, we can add a definite quantity of Thorium B to a known amount of a soluble lead salt. The radioactivity of this substance can be measured in terms of any arbitrary unit, such as the number of scale divisions per minute obtained with the electroscope used. Thus if 10,000 such units of Th B have been thoroughly mixed with 10 mg. of lead, it is clear that one unit of the Th B will then necessarily always indicate the presence of 0.001 mg. lead. Now we can prepare the lead chromate from the artificially activated lead by the usual chemical methods if we have kept the saturated solution of this compound sufficiently long in a thermostat at the desired temperature; we can determine its concentration by evaporating to dryness a few cc. of the solution, and measuring with the electroscope the activity of the almost invisible residue. A special advantage of the method is that the presence of foreign ions interferes in no way with the measurements as, of course, only the radioactive substance influences the electroscope. R. K. C.

Several experiments on the displacement of the equilibrium according to the Le Chatelier-Brown principle. W. A. ROTH. *Z. physik. chem. Unterricht*, **50**, 151–3 (July-August, 1937).—I. N_2O_4 is light in color, while NO_2 is deep brown. As the dissociation of N_2O_4 into $2NO_2$ takes place with the evolution of heat the gas becomes browner on heating. Expt.—Fill a glass tube in the shape of a tuning fork with the gas and seal it. Cool one branch in ice and place the other one in warm water. A difference in color results.

II. Hydrofluoric acid is a weak acid which ionizes with heat evolution while the heat of dissociation of acetic acid is zero. Hence hydrofluoric acid is more highly ionized at lower temperatures than at higher temperatures, while the degree of dissociation of acetic acid is practically independent of the temperature. Expt.—Fill a test-tube with a solution of celluloid in acetone. Pour out the solution and let the residual liquid evaporate. Introduce a two per cent. solution of hydrofluoric acid and a few drops of methyl violet and stir with a wooden splint or a paraffined glass rod. Place the lower half of the test-tube in ice and it will turn violet while the upper warm part stays blue. If 0.6 per cent. acetic acid is placed in another test-tube which is then cooled as above the color tone is hardly changed.

III. The neutralization of a dilute solution of a strong base with a dilute solution of a strong acid always yields the same heat of neutralization (+13.7 kg.-cal.) due to the reaction

$$H^+ + OH^- = H_2O + 13.7 \text{ kg.-cal.}$$

Because of the great negative heat of dissociation of water its dissociation increases greatly with temperature, and any reaction involving hydrogen and hydroxyl ions must speed up with a rise in temperature. Good illustrations are the hydrolysis of salts of weak acids or weak bases and the reversal of the neutralization of potassium cyanide.

$$KCN(aq.) + H_2O \rightarrow HCN(aq.) + KOH(aq.) \text{ or}$$
$$K^+ + CN^- + H^+ + OH^- = K^+ + OH^- + HCN(aq.)$$

Expts.—(*a*) Dissolve some ferrous ammonium sulfate in cold water in a test-tube; the solution becomes yellowish brown because of the formation of colloidal ferric hydroxide. When the upper part of the test-tube is heated nearly to boiling it becomes deep brown, leaving the lower cold part yellowish brown as more colloidal ferric hydroxide is produced in the warm solution. (*b*) A cold saturated solution of sodium bicarbonate is treated with phenolphthalein and the lower part of the vessel is placed in ice. The cold solution is nearly colorless while the upper warm part is reddish due to the formation of sodium hydroxide by hydrolysis. (*c*) An ammonium chloride solution is treated with litmus solution and a little ammonia until it becomes violet. As ammonia is a weak base some hydrochloric acid is formed by hydrolysis. When the upper part of the test-tube is heated nearly to boiling and the lower part is cooled in ice the color is reddish at the top and violet at the bottom.

Effect of pressure on the dissociation of weak acids. (*a*) In the system

$$H_2CO_3(aq.) \rightleftharpoons H^+ + HCO_3^-$$

the volume of ions plus water is smaller than that of non-dissociated acid because the water located between the ions is highly compressed due to the electrostatic attraction between the ions. Hence the dissociation increases with pressure. (*b*) Sea water contains dissolved carbon dioxide which is slightly ionized. Deep below the surface of the ocean where the pressure is many hundredths of atmospheres the bicarbonate ion concentration must be higher than at the surface. This is borne out by the sedimentation found. At the bottom of lakes calcium carbonate is found. At the bottom of deep seas where many bicarbonate ions are present a large amount of soluble calcium bicarbonate is formed, and the sedimentation found on deep-sea plumb lines is not calcium carbonate, but red clay. Thus the Le Chatelier-Brown principle serves to explain geological phenomena. L. S.

Of less and less. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **128**, 2–3 (Sept., 1937).—This article describes the numerous devices which the chemist now has to work with for complete analysis making it possible to utilize quantities smaller than were formerly thought necessary. The spectrograph is a newcomer among the instruments for identifying and evaluating metals. Perhaps even newer are X-ray diffraction studies of crystalline materials. Older analytical devices have undergone changes that have increased their value; such as colorimeters and turbidimeters; the photoelectric cell and vacuum tube galvanometers, however, are proving substitutes for the eye in such instruments.

Petrography, polarization studies, ultra-violet and ultra-microscopy, spot tests, refractometers, and polarimeters are but a few of the applications of many-sided instruments acting as glorified magnifying glasses. G. O.

HISTORICAL AND BIOGRAPHICAL

Bicentenary of Galvani. ANON. *Nature*, **140**, 391–2 (Sept. 4, 1937).—Luigi (Aloisio) Galvani, whose experiments paved the way for the work of Alessandro Volta, was born in Bologna on September 9, 1737, and was thus about eight years older than Volta. It was as an anatomist and physiologist, not as a physicist, that Galvani made his famous experiments on the muscular contractions of partly dissected frogs suspended by copper hooks from the iron rails of the balcony of his house. In awarding the Copley Medal to Volta in 1794 Sir Joseph Banks said that "he [Volta] has detected in the metals, which Dr. Galvani considered as mere agents in conducting his animal electricity, that very existing principle which the Doctor and his followers had overlooked." J. D. Forbes, however, concluded after careful study of Galvani's writings that "the great value of Volta's paper, at the time, was undoubtedly that it directed the attention of English experimenters to Galvani's discoveries . . ." In 1841 the Academy of Sciences of Bologna republished Galvani's writings in one volume. M. E. W.

Sir David Orme Mason, 1858–1937. J. READ. *Nature*, **140**, 534–6 (Sept. 25, 1937).—David Mason studied under Crum Brown at Edinburgh, and became Sir William Ramsay's first assistant. In 1886 he became professor of chemistry at the University of Melbourne, where he served with distinction until his retirement in 1923. His researches were concerned chiefly with the theory of solutions and chemical dynamics, atomic volumes at the boiling point, and ionic velocities. In 1895 he "evolved a modification of Mendeléeff's periodic system, which, apart from the treatment of the rare-earth metals, is practically identical with the later classification of Bohr. Masson's arrangement . . . contained spaces which were later filled by neon, krypton, xenon, and niton." In 1921 he put forth a proton-electron statement of the composition of atoms. M. E. W.

Van der Waals Centenary. ANON. *Nature*, **140**, 542 (Sept. 25, 1937).—"In commemoration of the birth of J. D. v. d. Waals on November 23, 1837, an international conference on interaction between molecules will be organized. . . ." The sessions will be held on November 25th, 26th, and 27th in the Van der Waals Laboratory at Amsterdam. M. E. W.

FOREIGN CHEMICAL AND EDUCATIONAL CONDITIONS

Freedom of science and learning. ANON. *Nature*, **140**, 169–70 (July 31, 1937).—"The group of British scholars and scientific workers who, under the leadership of Lord Rutherford, formed the Academic Assistance Council in 1933 wished to defend the principles of university freedom by actions rather than words. . . The Council has relied on the propaganda of practical achievement, not of protest or agitation . . . Of the approximately eight hundred refugee University teachers from Germany, four hundred sixty-five are permanently reëstablished and three hundred twenty have been provided with temporary positions enabling them to continue their scientific work." This movement "depends chiefly . . . on convictions that the principle of university freedom is involved and is implicitly defended by assistance for the refugee scholars . . . There are two hundred twenty-eight German *émigré* scholars in Great Britain, and it cannot be seriously claimed that they threaten the professional interests of the six thousand British university teachers. During the past four years, the Council alone has added a sum of £65,000 to the resources of the universities, which has enabled them to bear the additional strain. . ." M. E. W.

Alchema VIII through the eyes of an American chemical engineer. G. H. HARCOURT. *Chem. & Met. Eng.*, **44**, 423–6 (Aug., 1937).—The German Reich and chemical industry coöperated whole-heartedly and generously to make this world-famous chemical engineering exposition an unqualified success. The exhibits were, as far as possible, divided into groups and each group had been given a separate building or section of a building. In Hall I were found a complete collection of all sorts of glass, porcelain, and precious metal laboratory apparatus. Hall II contained full-scale apparatus constructed of non-metallic materials such as stoneware, acidproof brick, glass, silica, rubber, and synthetic resins. Another section contained a complete exhibit of all types of synthetic materials. Hall III(a) contained an apparatus for making the new fiber Zellwolle as well as xanthate and viscose. Hall III(b) had been converted into a library where German chemical literature was laid out on tables. Hall III was given over to exhibitions of apparatus which were in a sense only accessories to the chemical industry such as metal castings. Hall IV contained many large pieces of apparatus, such as digesters and evaporators. J. W. H.

GENERAL

Chemical problems in a museum of fine arts. R. J. GETTENS. *Rept. New Eng. Assoc. Chem. Teachers*, **38**, 132–7 (May, 1937).—One who visits a museum admires the objects on display for their beauty of design, painstaking workmanship, rarity, or great antiquity. One may not realize what an important rôle the physical and chemical properties of these things have played in telling the stories of past civilizations. Unfortunately, and often to the great regret of the archaeologist, the early craftsmen did not always choose materials for their durable qualities. Hardly a trace remains in the whole world of the art of the Greek painters which was described in glowing terms by classical writers. A major problem for the curator of a museum is the conservation, and often the restoration, of objects in his charge. Panel paintings from the more humid climate of Europe have a tendency to warp and blister in our heated museums. The natural decay and weakening of organic materials such as paper, leather, and textiles are inevitable. For the examination of works of art the museum investigator has made use of and adapted a few of the special instruments and technics of the physical chemist, notably the Roentgen ray, for determining whether there are indications of superimposed paintings, fluorescence analysis by filtered ultra-violet light for revealing restorations and for identifying materials, infra-red photography for similar purposes, chemical microscopy, and spectroscopy for identifying all sorts of materials and occasionally metallography and petrography. The museum restorer is constantly trying out new materials and methods in the restoration of works of art. Drying oils and natural resins used in varnishes have given trouble, and the conservator has welcomed the new contributions of the chemical industries in the way of synthetic resins and plastics. Some of the new synthetic resins—vinyl, acrylic, and styrene, for example—can be used to produce colorless and durable lacquers, fixatives, and adhesives which are of great service in this work. W. O. B.

RECENT BOOKS

CHEMICAL ARITHMETIC (School Certificate). *F. W. Goddard*, M.A., F.C.S., Senior Science Master, The College, Winchester. Longmans, Green and Co., New York City, 1937. vii + 99 pp. 12 × 18.7 cm. $0.65.

A first glance at this book causes some disappointment that it is not more suited for use in American schools, but a careful examination shows that there is apparently a need for such a volume in English schools. It should, therefore, justify its publication. Apparently English chemistry texts do not include the problems that form a prominent part of many American texts. To quote the preface, "I (the author) think that it is generally admitted by teachers that the supply of numerical questions, in readily accessible form, is rather inadequate and yet such questions are most useful when setting out of school work."

The author says correctly, "A knowledge of the principles of chemical arithmetic and a facility in dealing with the types of manipulation involved are of fundamental importance to the student of chemistry. . . . . .The principles involved are briefly explained, typical examples are worked out and there are about three hundred questions, all numerical, mostly taken from recent School Certificate papers set by the various Examining Boards."

The author, having the student's needs in mind, says, "In order to cater to the less intelligent pupils the questions are usually duplicated so that the boy who needs much assistance with one example will find another exactly similar one for his unaided attention. Further, the questions have also been carefully graded so that the able boy can progress by himself."

Specific points which caught the reviewer's eye included:

Chapter 1. The method of solving for the per cent. of water in crystallized borax might be improved upon. To multiply a common fraction which has no direct relation to one gram of crystallized borax by "100 grams of water" is not particularly good arithmetical reasoning. The older term "water of crystallization" instead of the newer and preferable "water of hydration" is used here as well as on pages 38 and 43. The problem illustrating the Law of Constant Composition (Definite Proportion) is cleverly chosen and well solved.

Chapter 2. The author does not differentiate between S.T.P. and N.T.P. as used in gas law problems, and throughout uses N.T.P. incorrectly as signifying 0°C. and 760 mm. It is a pleasure to note on page 7 problems involving both gas laws are solved not only by the $PV/T = P'V'/T'$ formula but also by the "common-sense" or "reasoning" method, called by the author working "from first principles."

Chapter 3. A good, though brief, introduction to solubility and solubility curves is followed by five problems in the use of curves.

Chapter 4. Equivalents seem to be unduly stressed, with four different types, eight illustrative problems, and forty-three test problems.

Chapter 5. Problems on the Law of Equivalent Proportions or Reciprocal Proportions seem beyond the first-year chemistry student or ill suited to his needs, while those of Multiple Proportions are appropriately reduced to a minimum.

Chapter 6 on atomic weights, valence, Law of Dulong and Petit, empirical formulas and molecular formulas is not so well presented. Incidentally, the appearance of such formulas as $ZnSO_4 \cdot 7H_2O$ shows that the author is not familiar with the better method, $ZnSO_4 \cdot (H_2O)_7$, adopted for hydrated salts by the Division of Chemical Education of the American Chemical Society and used by the Committee on Labels.

Chapter 7 is by far the longest chapter in the book and covers problems on Gay-Lussac's Law, Avogadro's Hypothesis, vapor density, gram-molecular volume, molecular weights, atomic weights (accurate and approximate), molecular formulas of gaseous hydrocarbons, Graham's Law of Diffusion and isomorphism. Many of the problems are complicated, simultaneous algebraic equations being used in one illustrative problem. The author's attempt to show when to use 22.2 and when 22.4 for the gram-molecular volume might be simplified by omitting all work with the former value.

Chapter 8 on chemical equations and reacting quantities comes back to the first-year student's level with a few well-chosen examples. Curiously enough, the weight-volume and volume-weight types of problems are not developed.

Chapter 9 on volumetric analysis slips back to more advanced work again, and impresses the reviewer as too brief a treatment for collegiate work and too much for the simple treatment of molar and normal solutions considered by many as sufficient for elementary students.

The last eight pages of the book contain tables of logarithms and antilogs, pressure of aqueous vapor, approximate atomic weights, and, best of all, the answers to all the problems. The list of answers is marred somewhat by common fractions linked with metric units and the omission of the answers that "explain" why certain numerical answers are obtained. Naturally, no attempt was made to test the accuracy of the answers, as credit for such work is given in the preface. Eye-strain which might result from consulting the table is cleverly eliminated by printing the numbers of the problems in large bold-faced type and the answers themselves in roman type.

Teachers who are not sufficiently supplied with problem material will doubtless appreciate access to this little book when they want a problem a little different from those they are using.

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ANNUAL REVIEW OF BIOCHEMISTRY, Volume VI. *James Murray Luck*, Editor, Stanford University. Annual Review of Biochemistry, Ltd., Stanford University P. O., California, 1937. ix + 708 pp. 14.5 × 22 cm. $5.00.

Volume VI of the Annual Review of Biochemistry (1937) contains the following reviews:

"Permeability," R. Collander (pp. 1–18); "Biological Oxidations and Reductions," F. Lipman (pp. 19–42); "Enzymes," K. Linderstøm-Lang (pp. 43–72); "The Application of Microchemistry to Biochemical Analysis," P. L. Kirk (pp. 73–98); "The Chemistry of the Carbohydrates and the Glycosides," W. N. Haworth and E. L. Hirst (pp. 99–114); "The Chemistry of the Lipins," E. Klenk and K. Schuwirth (pp. 115–38); "The Chemistry of the Steroids," R. Schoenheimer and E. A. Evans, Jr. (pp. 139–62); "The Chemistry of the Proteins and Amino Acids," G. S. Adair (pp. 163–92); "The Chemistry and Metabolism of the Compounds of Sulfur," V. du Vigneaud and H. M. Dyer (pp. 193–210); "Chemistry and Metabolism of the Nucleic Acids, Purines, and Pyrimidines," F. Chrometzka (pp. 211–24); "Carbohydrate Metabolism," H. J. Deuel, Jr. (pp. 225–44); "Fat Metabolism," R. G. Sinclair (pp. 245–68); "The Metabolism of Proteins and Amino Acids," S. Edlbacher (pp. 269–90); "Detoxication Mechanisms," A. J. Quick (pp. 291–302); "The Hormones," G. F. Marrian and G. C. Butler (pp. 303–34); "The Vitamins," C. C. Sherman and H. C. Sherman (pp. 335–74); "Nutrition (Energy Metabolism)," M. Kleiber (pp. 375–94); "The Biochemistry of Muscle," D. M. Needham (pp. 395–418); "The Metabolism of Brain and Nerve," R. W. Gerard (pp. 419–44); "The Biochemistry of Fish," C. M. McCay (pp. 445–68); "Chemical Embryology," D. M. Whitaker (pp. 469–88); "Plant Pigments," J. H. C. Smith (pp. 489–512); "The Alkaloids," E. Späth (pp. 513–34); "Photosynthesis," R. Emerson (pp. 535–56);

"Mineral Nutrition of Plants," F. G. Gregory (pp. 557–78); "Organic Acids of Plants," T. A. Bennet-Clark (pp. 579–94); "Biochemistry of Bacteria," C. B. van Niel (pp. 595–620); and "Immunochemistry," K. Landsteiner and M. W. Chase (pp. 621–44).

The volume also contains author and subject indices.

OTTO REINMUTH

THE UNIVERSE SURVEYED. *Harold Richards.* D. Van Nostrand Co., Inc., New York City, 1937. xvii + 722 pp. 94 figs. 15 × 22 cm. $3.50.

In the preface Professor Kirtley F. Mather, chairman of the department of geology at Harvard University, states that the book is intended "as a text for the junior-college or freshman-year course designed to give a general introduction to physical science." It is an integration of some of the fundamental ideas of physics, chemistry, astronomy, and geology.

The main portion of the book is divided into four "units." The word "unit," however, does not have the specific meaning used by students of the Morrison Plan. The introduction is a general discussion of the relation of science to the modern word and to philosophy.

Unit 1, "The Earth as an Astronomical Body and Our Neighbors in Space," requires eighty-five pages, and is subdivided into three chapters. In the chapter "Falling," a long excursion into history is taken, from Aristotle's early views to Newton's Law of Gravitation. In the chapter "Some Consequences of Gravitation," nineteen diverse topics such as centrifugal force, molecular motion, and sunset phenomena, are discussed. In the chapter "The Origin of the Solar System" the age of the earth and tidal action are discussed, and, after the falsity of the nebular hypothesis has been shown, the planetesimal hypothesis is presented.

Unit 2, "The Nature of Matter and Energy," requires one hundred eighty-two pages and consists of six chapters. In the chapter "Background for Energy," the author enters the philosophical question of the nature of reality, and this thorny subject recurs many times throughout the book. In the same chapter, in another historical excursion, the knowledge from the Greeks to Newton is summarized. In the chapter "Conservation of Energy" seventeen diverse topics such as kinetic energy and work, "definitions versus reality," peculiarities of water, and a "triumph of youth" are discussed. The remaining chapters follow the same plan. The content is indicated by the titles: "Atoms and Molecules," "Chemical Transformations," "The Nature of Heat," "Electricity and Matter," and "Radiant Energy and Atomic Structure."

Unit 3, "The Controlled Changes, or Forced Evolution, of our Physical Environment," requires one hundred ninety-three pages. It is essentially a discussion of the practical application of physical sciences. It is subdivided into four chapters: "Science and Invention," "The World's Work," "Materials," and "Communication."

Unit 4, "The Uncontrolled Changes, or Geological Evolution of Our Physical Environment" requires ninety-five pages. It is subdivided into three chapters: "The Weather," "Some Geological Processes at Work, " and "The History of the Earth."

In the "Conclusion: The Frontiers of Physical Science," topics such as relativity, quantum theory, transmutation of elements, the principle of uncertainty, and the expanding universe are discussed. The "Astronomical Supplement" is essentially a guide to amateurs for observations in the sky. The appendix contains a list of eight hundred fifty true-false statements, which may serve as a review.

As it appears from the preceding discussion, the book is comprehensive in scope and will commend itself to anyone engaged in teaching such a course. The major divisions are reasonable, and the space alloted to each is well balanced. The author seems to possess considerable erudition, and the information contained in the book, though not always stated with scientific precision, is essentially accurate. Its usefulness as a text, however, will depend upon the desirability of certain peculiarities of the book.

The book is synthetic in character. The origin, development, and the various implications (philosophical, social, political, economic) of the scientific concepts are discussed, but the concepts themselves are not treated analytically. The experimental background and the logical derivation of the concepts therefrom are rarely given. The concepts are not clearly explained and often they are not defined. Scientific terms are copiously introduced without any forewarning, and, if an explanation follows, the relation is seldom made clear. The reader will be unable to follow unless he is already familiar with the field.

The style of the book is subtle and partakes something of adventure. While it is inspiring in many places, the frequent lapsing into ecstasies is likely to give the impression of superficiality. Further, while a simile or a metaphor is refreshing to one who understands the relationships, it is likely to be confusing to one not acquainted with the field. The beginner would be thankful for simpler and more direct language.

It is regrettable that the logical organization of the major divisions is not carried into the chapters. Many topics having little in common fundamentally are treated in the same chapter. Digressions are numerous, and apparently consciously made. Many ideas are discussed without regard to their logical sequence. For example, molecular motion is discussed in "Consequences of Gravitation," long before "Atoms and Molecules" is studied.

Finally, the reviewer does not feel that the space and emphasis devoted to the question of the nature of reality in a book of this kind, is desirable. Statements such as "evidently a few equations are to be regarded as the only language in which the underlying nature of the material universe can be adequately expressed" (p. 586), aside from the fact that they are debatable, tend to mystify and confuse the student, without imparting any definite ideas.

THEODORE A. ASHFORD

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CHICAGO, ILLINOIS

ANNUAL SURVEY OF AMERICAN RUBBER CHEMISTRY FOR 1936 *Webster N. Jones,* Carnegie Institute of Technology, Pittsburgh, Pennsylvania. 40 pp. 15 × 23 cm.

"For ten years (1925–1935) the National Research Council sponsored the Annual Survey of American Chemistry. . . .Unfortunately, because of the lack of financial resources, the National Research Council has discontinued the Informational Service under which the Annual Survey has been prepared.

"In order to insure continuity of the Survey of American Rubber Chemistry, and with the hope that future publication will be resumed, the City of Pittsburgh sponsored this study, which used workers provided by the Civil Works Administration and the Works Progress Administration. The Carnegie Institute of Technology furnished the supervising personnel and the facilities necessary for carrying on the work. Through the coöperation of Dr. Robert E. Doherty, President of the Carnegie Institute of Technology, this bulletin has been made available to the public."

CHEMISTRY AND COOKERY. *Annie Louise Macleod,* Ph.D., Dean of the College of Home Economics, Syracuse University, and *Edith H. Nason,* Ph.D., Professor of Foods, Syracuse University. Second Edition, McGraw-Hill Book Co., Inc., New York, 1937. xiv + 568 pp. 25 figs. 14.5 × 20.5 cm. $3.50.

The authors recognize the difficult task of selecting from the vast fund of chemical information and principles the material most suitable for the needs of the home economics student. Educational pressure bears down on specialized fields at the expense of a broad background of fundamental training. The second edition of this book will continue to meet the needs of a condensed course, the purpose of which will be to lay a foundation for cookery processes with the chemistry necessary to explain the

composition of foods and the changes that occur in foods during cooking.

In the second edition of CHEMISTRY AND COOKERY, the theory of ionization, hydrogen-ion concentration, and acidimetry and alkalimetry are treated in accordance with the Debye-Hückel and Brønsted theories, which brings this work in line with recent conceptions. Likewise, the chapters relating to egg and meat cookery have been revised to include the ideas recently developed through experimental work in foods.

Especially interesting are the applications of chemistry to home economics problems in relation to the use of foods which leave a basic residue in the body, the influence of acid in the formation of fruit jelly, solution tension in cleaning silver, and the position of an element in the electrochemical series and its usefulness in making household utensils. The transition from inorganic to organic chemistry is nicely made through a review and introductory chapter. Continuing the study of organic chemistry, the following types of compounds are discussed: hydrocarbons, alcohols, aldehydes and ketones, acids, esters, oils and fats, carbohydrates, proteins, and cyclo-organic compounds. These organic compounds are discussed in relation to the foods of which they are a part; for example, the proteins of meat, eggs, flour, and cereals, the organic acids of fruits, the esters present in flavoring extracts, the composition of vitamins and of the pigments of fruits and vegetables.

The textbook includes a laboratory manual of chemistry and cookery. To the reviewer, the laboratory work in chemistry seems entirely inadequate from the standpoint of contact with materials and of experience in setting up apparatus. Especially desirable are such related lessons as supersaturated solutions and candies and frozen desserts, normal solutions and concentration of acids in vinegar, fruit juices and sour milk, colloids and mayonnaise salad dressing, starch cookery, and gelatin desserts.

The chapters in the text and the experiments in the manual lead in desirable sequence from one to another, each making use of principles previously studied. For such a condensed course in chemistry and cookery, the material is carefully chosen. The book is well bound and printed.

NELLIE M. NAYLOR

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HANDBOOK OF CHEMISTRY. *Norman A. Lange*, Lecturer in Organic Chemistry at Cleveland College of Western Reserve University. Second Edition. Handbook Publishers, Inc., Sandusky, Ohio, 1937. xvi + 1501 pp. + 249 pp., mathematical appendix, + 30 pp., indices. 13.2 × 19.2 cm. $6.00.

The first edition of this handbook, which appeared during the closing months of 1934, was so well received by industrial and academic chemists, that it was only natural that a revised and enlarged edition should be forthcoming.

The second edition is a thorough revision of the first, with changes on over four hundred pages. Gravimetric and volumetric factors, as well as molecular weights, have all been changed to conform with the new 1937 atomic weights. The page width has been slightly increased to make for greater accessibility of subject matter along the inside margin. This extensive revision and inclusion of new material has increased the size of the volume by two hundred thirty-seven pages.

The section on the nomenclature of organic compounds has been enlarged. It includes a discussion of the older and Geneva systems in addition to thirteen pages of the more important organic ring systems giving names and numbering. The Beilstein references given in the first edition have been augmented to include references of later volumes. Three thousand nine hundred compounds are listed in the order of their refractive indices. Several thousand organic compounds are arranged in accordance with the values of their melting points. The formula index of organic compounds is arranged in essentially the same method used in Richter's LEXIKON DER KOHLENSTOFF VERBINDUNGEN. There is a new and enlarged section on organic reagents for inorganic analysis. The following new tables are offered.

Organic Ring Systems
Formula Index to the Compounds Listed in the Table of Physical Constants of Organic Compounds
Melting Points of Organic Compounds Arranged in Ascending Order of Melting Points
Refractive Index of Isotropic Solids, Uniaxial Positive and Negative Crystals, Biaxial Positive and Negative Crystals, Pure Liquids, Water and Aqueous Solutions of Halogen Acids, Aqueous Solutions of Alcohol, Aqueous Solutions of Glycerol
Formula Index for Finding Organic Compounds Listed in the Refractive Index Table
Calculations of Refractive Index
Table for the Conversion of Immersion Refractometer Reading to True Refractive Index
Viscosity of Aqueous Glycerol Solutions for Calibration of Viscosimeters
Formulas and Properties of Denatured Alcohols
Authorized Use of Denatured Alcohol Formulas

The author and publishers have enhanced the value of this excellent handbook in its revised and enlarged form. It is heartily recommended by the reviewer.

M. H. DASKAIS

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THE WORLD OF ATOMS. *Arthur Haas*, University of Notre Dame. Translated by George B. Welch. Second Edition, enlarged and revised, D. Van Nostrand Company, Inc., New York City, 1937. xiv + 183 pp. 54 figs. 15 × 23 cm. $3.00.

This is a well-connected and entirely non-mathematical account of the development of atomic physics. The reader is led naturally to appreciate the evolving concepts of the theory by a lucid and pictorial description of the experiments responsible for their introduction. The book is highly recommended to the interested layman, and to the medical practitioner engaged in radiation therapy. Also, it should be a stimulating and informative addition to the reading of students of elementary physics and chemistry.

The present volume, which is a revision of that published in 1928, has been modernized to about the middle of 1936 by the introduction of much new material, including additional lectures on the results of atomic disintegration, and on cosmic rays. The latter are accompanied by numerous excellent reproductions of cloud chamber photographs.

S. L. QUIMBY

COLUMBIA UNIVERSITY
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INDUSTRIAL CHEMISTRY. *Emil Raymond Riegel*, Ph.D., Professor of Industrial Chemistry, University of Buffalo. Third Edition. Reinhold Publishing Co., New York City, 1937. xiii + 851 pp. 275 figs. 15 × 23 cm. $5.75.

Anyone who has the courage to write an INDUSTRIAL CHEMISTRY has our sincere sympathy and respect. The new edition of Dr. Riegel's book is well worth serious consideration by all teachers of industrial chemistry.

As the author states, certain material has been added, notably recent work on polymerization, solvent extraction, glass, ammoniated superphosphates, sugar from wood, new solvents, synthetic rubber, new uses for rayon, recent developments in stainless steel and other alloys. The principal addition is the appearance of more production figures which are always of interest to the instructor.

The outstanding chapters are perhaps the first eleven in which such common subjects are covered such as sulfuric acid, caustic soda, synthetic ammonia, etc. Other important chapters are on wood distillation, fermentation, dyes, and metals.

Some readers will be disappointed in the treatment of the cracking processes. The subject matter given is considerably out-of-date. More material could have been presented on synthetic resins, varnishes, and enamels, which subjects are of more interest today than lacquers.

The chapter on patents, chemical engineering equipment, and materials used in the industry might be eliminated without seriously detracting from the value of the book. Such subjects do not necessarily come under the head of industrial chemistry.

No two instructors of industrial chemistry will ever completely agree upon the material that should be presented or the method of presentation. It can, nevertheless, be said, without fear of contradiction, that Dr. Riegel's ideas on the subject are held by the majority.

The author and the publishers should be congratulated on keeping this very complete treatise at a price within reason.

D. B. KEYES

UNIVERSITY OF ILLINOIS
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A LABORATORY MANUAL OF GENERAL CHEMISTRY. *James H. Walton* and *Francis C. Krauskopf*, Professors of Chemistry in the University of Wisconsin. The Collegiate Press, Menasha, Wisconsin, 1937. ix + 317 pp. 15 × 23 cm. $2.00.

This manual is designed to cover the first semester of the standard college chemistry course. In addition to the laboratory directions and related material, there are lessons on such topics as valence (four pages), colloids (four pages), factors influencing chemical change (three pages), and chemical arithmetic (fourteen pages). A short chapter on how to study chemistry, a set of study outlines and several tables of data which are used in the course are also included.

Of the two hundred sixty pages comprising the main portion of the book, two hundred thirteen are devoted to the more or less standard types of experiments on the non-metals and theoretical chemistry, including organic chemistry and the colloidal state. The remainder contain a group of "Special Experiments," which can be assigned to the better, or more interested, students. These deal with the hardness of water, determination of molecular weights, preparation and properties of alloys, degree of ionization, hydrogen-ion concentration, electrochemistry, liquefaction of sulfur dioxide, determination of available oxygen in hydrogen peroxide, measurement of the speed of a chemical reaction, oxidation and reduction, and complexions. There are no experiments on the chemistry of metals.

The book has several distinctive features. Many of the experiments are accompanied by "Introductory Statements" which outline the principles involved and arouse the student's interest. Each experiment is followed by a list of questions, the answers to which the student is to write on the right-hand page, with his notes on the experiment. Tabular forms for the recording of data are furnished on most pages. There is a considerable number of new and ingenious experiments.

The authors have produced a well-written and highly teachable manual which deserves careful examination by college chemistry teachers.

JOHN C. BAILAR, JR.

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EVERYDAY SCIENCE. *A. W. Haslett*, sometime Foundation Scholar of King's College, Cambridge. Alfred A. Knopf, Inc., New York City, 1937. xiv + 305 + xii pp. 14 × 20.5 cm. $2.75.

Mr. Haslett, who has also written UNSOLVED PROBLEMS OF SCIENCE, is the science correspondent of the London Morning Post. He writes as a journalist for the layman, the book being "devoted to science as it effects our everyday life." One of his chief aims is to give the reader some of the background necessary to the formation of intelligent opinion about the social problems arising from the application of scientific discoveries. Another of his aims is to show that fundamental research "is the most paying form of investment." The chapter titles, The Builder's Problem, Science and Crime, Farmer *versus* Nature, the Problems of Waste, are indicative of the range of subject matter treated in the twelve chapters. One is almost tempted to say that the choice of material has been conditioned by the amount of emphasis placed upon it in the daily press.

The author has been quite successful in attaining both of the above-mentioned aims. He writes in a reserved style, and is conscious of both the power as well as the limitations of science. He gives evidence of sound judgment, and makes reasonable evaluations of scientific problems. He is at his best in reporting experiments and describing social and scientific developments; and at his poorest in making scientific explanations. Some inaccuracies betray lack of scientific thoroughness. To take a specific example, the discussion of the second law of thermodynamics (page 245 *seq.*) is quite devious. The second formula for the efficiency of a perfect engine is wrong (page 248); there is unnecessary confusion about what temperature is cited, and it is not immediately evident how the efficiencies at various temperatures were obtained. Of course, it is questionable whether any popular treatment of such subjects can be successful.

From the point of view of science education, the book is not intended, and cannot serve, as a basis for intensive study. It may be used, however, for optional general reading in connection with orientation courses in the physical sciences or in social studies. It will serve best mature readers, who are not primarily interested in science.

THEODORE A. ASHFORD

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CHICAGO, ILLINOIS

TEXTBOOK OF INORGANIC CHEMISTRY. *J. R. Partington*, M.B.E., D.Sc., Professor of Chemistry in the University of London, Queen Mary College. Fifth Edition. The Macmillan Company, New York City, 1937. viii + 1062 pp. 390 figs. 13 × 19.5 cm. $4.60.

The fifth edition of this well-known textbook appears four years after its predecessor. The author has made minor alterations throughout the entire book and has successfully incorporated a summary of the more important advances. These additions are made without material changes in the paging, by slight condensations and an occasional omission of material of minor importance. There are a few places in which more extensive changes are to be noted. Three-quarters of a page has been added upon deuterium and heavy water; three and one-half new pages upon the structure of silicates have been inserted; while smaller amounts of space are devoted to the revision and discussion of such topics as atomic structure, theory of indicators, thermochemistry, halogens, fixation of nitrogen, and the noble gases. These changes have been skillfully incorporated in the text so that the fifth edition is a thoroughly modern textbook with the same table of contents as the fourth edition, while the indices of the two editions might be interchanged without difficulty. The illustrations are, in general, the same as those in the fourth edition, although a few of the line drawings have been remade, and halftones are clearer in the new book. The new edition retains the approved educational features of the former editions, such as chapter summaries, review questions, and answers to problems. Some of the questions are new and their position at the end of the book is undoubtedly popular with educators.

The Partington textbooks have been known too long and too favorably to require comment here. The fifth edition is fully up to the high standard which has been maintained in previous editions. It is an advanced inorganic textbook which is modern, complete, concise, accurate, and teachable.

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PREVIEW *OF THE* SIXTEENTH EXPOSITION *OF* CHEMICAL INDUSTRIES

Corning Glass Works—332, 333, 346, 347

Corning Glass Works will exhibit many new items in "Pyrex" Brand Laboratory Glassware, together with displays of standard items, complete units of laboratory apparatus, and equipment for industrial applications.

Mine Safety Appliances Company Exhibit—210B–210C

A number of new and improved items of safety equipment will be exhibited by the *Mine Safety Appliances Company*. These will include the explosimeter, the One-Hour Oxygen Breathing Apparatus, the Mercury-Vapor Detector, a salt tablet dispenser, the M.S.A. Lamb Ventair, a combustible gas alarm, the All-Weather First Aid Kit, and an improved line of hose masks.

Hanovia Chemical and Manufacturing Company—222

This exhibit will include the *Hanovia* Irradiator for producing irradiated Vitamin D Milk and other Vitamin D substances, the Safe-T-Aire *Hanovia* ultra-violet lamp which sterilizes the air, and the *Hanovia* quartz mercury arc lamp which are used for the applications of ultra-violet radiations.

Kewaunee Manufacturing Company Exhibit—251–253

The *Kewaunee Manufacturing Company* will exhibit complete equipment for a modern research laboratory in metal, with a number of items recently developed in special laboratory fittings, and included with this exhibit will be several *Karcile* laboratory sinks, a recent research development at the Mellon Institute of Industrial Research, Pittsburgh, Pennsylvania.

The exhibit will feature a series of wood carvings, after paintings and etchings by such famous artists as Teniers and Brosik. These carvings include such views as "The Alchemist," "The Oratary and the Laboratory," and others, and are done by the *Kewaunee Manufacturing Company's* master carver.

Fish-Schurman Corporation—221

Fish-Schurman Corporation will display an extensive line of laboratory equipment, including the New Ubbelohde Viscosimeter, the Hoeppler Viscosimeter, the Ultra-Thermostat, *Jena* Optical Glass Color Filters, *Jena* Fritted Glass Filters, a full line of *Jena* optical glass, and Royal Berlin Porcelain Ware.

Carl Zeiss, Inc., Exhibit—316–317

This exhibit will include microscopes and accessories for use in chemical laboratories, industrial and research work; Abbe, Dipping, Sugar and Oil, and Hand Sugar Refractometers, as well as a special hand instrument for tomato industries. Spectroscopes, Polariscopes and Polarimeters, and the Pulfrich Photometer for clinical and industrial research will also be exhibited.

Hellige, Inc., Exhibit—271–272

The *Hellige* display will include an Electrometric pH-Meter with a glass electrode for pH, measurement of oxidation-reduction potentials, etc., a Vacuum-Tube Galvanometer for use with precision potentiometers, and a glass electrode for sensitive pH determinations. A complete line of glass electrodes and auxiliary equipment, together with a Duboscq Colorimeter which permits readings to 0.01 mm. without the use of a vernier scale will also be featured, as well as full range simplex potentiometers, comparators for the colorimeteric determinations of pH and other tests, and other allied apparatus and accessories.

Scientific Glass Apparatus Company Exhibit—300

Scientific Glass Apparatus Company is adding three entirely new features to their standard line of fine glassblowing. They are (1) Metal Clad Joints, proved by a year of hard usage in a large chemical laboratory, which form non-locking seals; the metal surfaces are not affected by corrosion; (2) Ful-Jak Condensers, which fully enclose the condenser tube and ground joints in the water jacket; and (3) Pyrex glassware which is fused in blue graduation enamel. Effective December 1 all graduations in Pyrex ware will be filled with a blue enamel. This enamel will be fused in at a high temperature until it becomes an integral part of the apparatus. It is resistant to all cleaning solutions, eliminates glare, and promotes greater readability.

Christian Becker, Inc., Exhibit—44A

In addition to their latest Chainomatic models, *Christian Becker, Inc.*, will exhibit improved micro balances, a magnetically damped balance giving automatic weighings from $^1/_{10}$ to $^1/_{100}$ mg. and a Keyboard analytical balance. Several heavy capacity balances and a full line of Torsion balances will also be shown.

Lancaster Iron Works, Inc., Exhibit—429

The exhibit of the "Lancaster" Mixer manufactured by *Lancaster Iron Works, Inc.*, will be a model of the EAG-4 unit which is one-fourth the actual size of the original mixer. The Company expects to run demonstrations and develop formulas which pertain to the use of the "Lancaster" Mixer in the laboratory, as well as in the chemical industries.

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Owens-Illinois to Exhibit Fiberglas at Exposition—491–492

Owens-Illinois Glass Company will present a comprehensive display of Fiberglas, an inorganic textile material developed after years of continuous research in the company's Industrial and Structural Products Laboratory, Newark, Ohio.

Although other *Owens-Illinois* contributions to the Industry will be on exhibit, major attention will be focused on Fiberglas materials—yarns, cloths, tapes, and other textile forms—and their uses in the chemical and allied industries.

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Coleman pH Electrometers—338–339

The Model 3 *Coleman* pH Electrometers manufactured by the *Coleman Electric Co., Inc.*, are light weight, portable, precision instruments for the determination of pH with the glass electrode, and for redox measurements in field, factory, or laboratory. The instruments are completely self-contained, and the sturdy glass electrode is so mounted that accidental breakage is almost impossible, while both the glass electrode and the redox electrode are of the exclusive *Coleman* sealed construction. The instrument is very simple to operate, requires no calculations, and can be read directly in pH. Automatic temperature compensation is optional.

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T. Shriver & Company Exhibit—12

The *Shriver* booth will contain a filter press in actual operation showing the pumping and flow of liquid and filtration of a typical solution.

There will be on display a great many samples of various chemical, pharmaceutical, and food products showing the contrast between the unfiltered and filtered materials.

A *Shriver* Diaphragm Pump will be shown. Its construction features and its particular adaptability for pumping of corrosive, abrasive, and other materials which are hard to handle will be indicated.

Bausch & Lomb Optical Company Exhibit—483–484

The *Bausch & Lomb* exhibit will consist of optical instruments especially selected for and pertinent to their application in chemical work.

There will be a showing of compound microscopes, both polarizing and laboratory type, colorimeters, refractometers, spectrographic, and photomicrographic equipment.

New Proctor Dryers to Be Displayed—15A–B–C

New dryers manufactured by *Proctor and Schwartz, Inc.*, which are to be exhibited will include the new *Proctor* Package Yarn Dryer, the Twelve-Tray Dryer, the Laboratory Dryer, the Two-Truck Dryer, and the Aëro-Form Dryer.

The principle of the new *Proctor* Reversing Pan Dryer will be demonstrated by a small unit showing the conveyor system. This type of dryer is unique for drying materials which must be disturbed or agitated during the drying process.

Eppenbach, Inc., Displays New Homo-Rod Mixer—318

Eppenbach, Inc., will exhibit their Homo-Rod Mixer which is used for premixing and agitating. Its principal novel feature is that it sucks the material to be processed from the bottom and discharges toward the top, thus avoiding any possibility of incorporating air into the mixture to be processed. The mixer is adjustable for various sizes of tanks.

If there is any tendency for a heavier liquid or other material to settle in the bottom of the tank it is picked up from its point of maximum construction and discharged upward to be mixed perfectly with the rest of the material.

United States Steel Exhibit—19–20

The *United States Steel* exhibit will feature USS Stainless Steels as applied in various chemical processes with action provided by two moving laboratory tests.

A test will be conducted to show how USS Stainless Steel samples do not scale at high temperatures. Another test will reveal the resistance to corrosion of USS Stainless Steel when exposed to boiling nitric acid. A third corrosion test will have stainless steel and mild steel samples moving through aërated acetic acid to show the comparative corrosion resistance of stainless and ordinary steels in alternating wet and dry conditions.

Arranged in the exhibit space will also be several fabricated products made of USS Stainless Steels, and an array of samples to show the various finishes in which stainless steels may be obtained. Pans, dippers, and other deep drawn containers will be displayed.

There will be a pictorial display illustrating the corrosion resistance of Lumnite Cement to acids, alkalies, and other chemicals and a tubular display showing USS National Scale-Free Steel, USS National Copper Steel, and USS National Duroline Pipe. Subsidiary companies participating include *American Steel & Wire Company, Atlas Lumnite Cement Company, Carnegie-Illinois Steel Corporation*, and *National Tube Company*.

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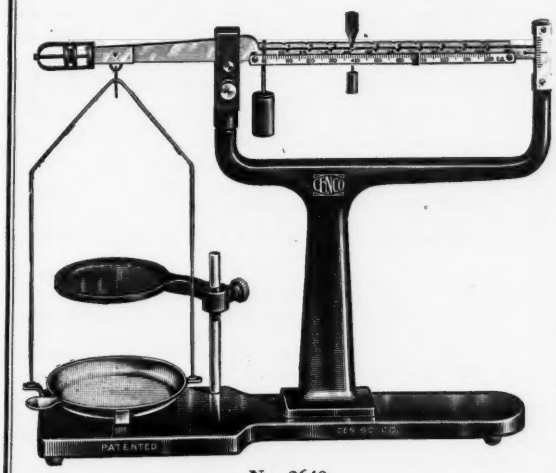

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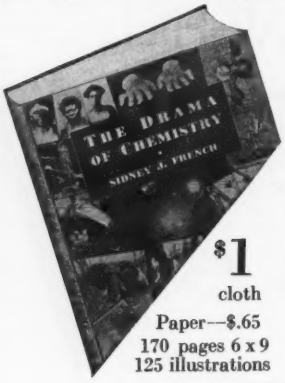

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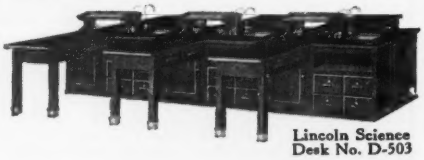

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Precision Scientific Company Exhibit—334–335

Precision Scientific Company will exhibit representative models of Freas constant temperature laboratory equipment, including water baths, incubators, and ovens; "Precision" automatic water stills; Kjeldahl equipment for digestions and distillations; Ful-Kontrol heaters; Hy-Temp burners; and various types of laboratory stirrers.

Fletcher Works, Inc., Exhibit—58

Fletcher Works, Inc., will exhibit a 40″ *Fletcher* suspended centrifugal in operation, equipped with mechanical unloader and "Centroid" speed control, which provides a safe and efficient unloading speed of 50 R.P.M.

Another feature of this exhibit will be a new 12″ "Standard" laboratory centrifugal, an underdriven machine with V-belt drive. Interchangeability of baskets, high speed, and absolute cleanliness are features of this centrifugal.

Eastern Engineering Company Exhibit—439–440

Portable mixers, laboratory stirrers, and the Precision Temperature Regulator will be featured in the exhibit of the *Eastern Engineering Company*, as well as a number of other items.

Highlights of the L & N Exhibits at the Chemical Show—55

Recent developments in the use of Micromax recorders and control equipments, and several new instruments for plant and laboratory, will be shown by *Leeds & Northrup*.

A new and improved apparatus for measuring and recording CO_2 will be in operation. This equipment, using a much simplified cell assembly, measures quickly, accurately, and with little maintenance. No chemicals are needed. All surfaces in contact with the gas in the measuring cell are of such nature that corrosion and catalytic action are definitely avoided.

Our recently developed Micromax Electric Control will be shown as it is applied to automatic control of corrective water treatment in municipal and industrial filter plants, and in industries using process water.

Several new laboratory instruments for the accurate measurement of pH will also be shown.

In addition to these new instruments, there will be indicators, recorders, and controllers for the measurement and/or control of conductivity and temperature. Laboratory instruments for the measurement of pH, conductivity, and temperature will also be exhibited, some with their respective primary elements. Other miscellaneous equipment includes the general-purpose K2 potentiometer, the Type S (Wheatstone bridge) test set and galvanometer.

W. A. Hammond Drierite Company Exhibit—284

This display will consist of a general line of *Drierite* products arranged to suggest applications of *Drierite* in the general chemical and engineering industries. It is anticipated that models showing methods of application, efficiency, etc., of *Drierite* in the drying of organic liquids, the common refrigerants, and the industrial gases will be shown.

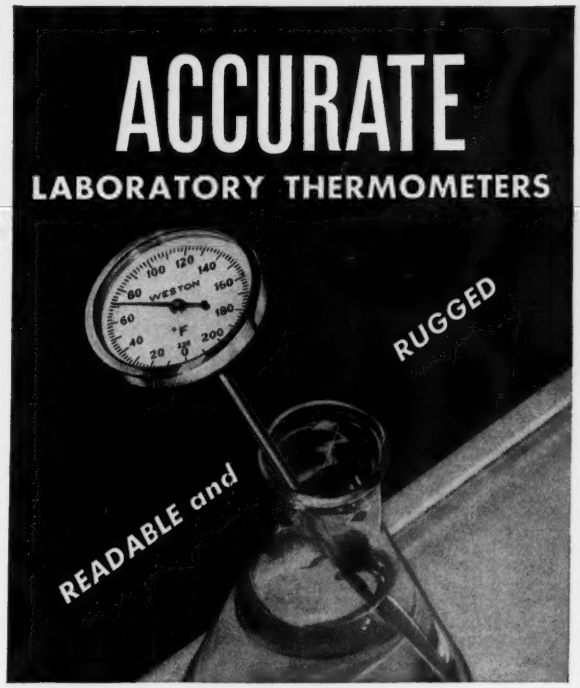
C. J. Tagliabue Mfg. Company—48

C. J. Tagliabue Mfg. Company, manufacturers of indicating, recording, and controlling instruments for temperature, pressure, level, flow, humidity, time; oil testing instruments; laboratory thermometers and hydrometers, will display a radically new TAG CELECTRAY Recorder with a sensitive mirror galvanometer as the primary controlling element. In this design an inertialess beam of light takes the place of the customary metal boom or pointer. The beam of light from the galvanometer in moving on and off a phototube passes "the controlling edge" of a screen, thus operating relays which in turn control a reversing motor which drives the moving contact of the wheatstone bridge or potentiometer.

Another new and important instrument that will be shown for the first time is a unique float-type Level Controller. It is designed with two simple adjustments to meet changing plant conditions: one, for the maximum or minimum level; and the other for throttling range.

In addition, a complete line of pressure spring instruments of advanced mechanical construction in new rectangular cases will be shown.

On the other display panels TAG Magnetic Clutch Flow Instruments, TAG Industrial Thermometers, TAG Chemical Thermometers and Hydrometers, and Oil Testing Instruments will be prominently featured.



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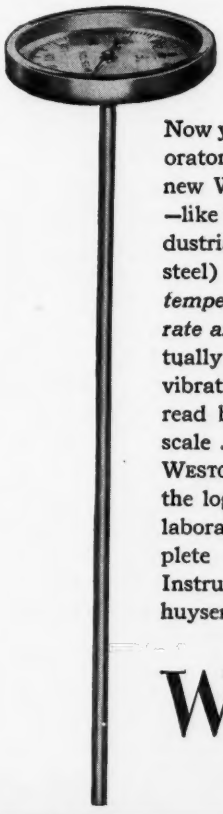

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Adoptions in institutions of all types in all parts of the country prove beyond doubt the success of the innovations in technique and emphasis in this new text. Its perfected semi-micro technique and stress on chemical equilibrium have a wide appeal. And since no drastic changes in equipment are necessary, its introduction as a text is completely practicable. $2.75

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NEWS

The advertising pages of the JOURNAL are full of news about things that are helpful in your work.

Read these news pages . . . and when writing to advertisers mention the JOURNAL OF CHEMICAL EDUCATION.

Barnstead Still & Sterilizer Co. Exhibit—344–345

This exhibit will include one of the *Barnstead* commercial or industrial type water stills which has a capacity of fifty to five hundred gallons of distilled water per hour. These units of larger distillation capacities have recently been completely redesigned to provide new operating efficiency.

Other items on display include the *Barnstead* extra duty, or hard water type stills, a *Barnstead* Solvent Recovery still which is used for reclaiming to their original condition all kinds of solvents which have become contaminated from use in cleaning, stripping, or degreasing operations, as well as the regular small laboratory stills in steam, gas, and electrically heated models, including a fully automatic electrically heated still and tank combination which operates itself.

Another feature of the exhibit will be the *Barnstead* Soxhlet Extractor which provides an economical means of continuously extracting oils, fats, etc., from solids by means of solvents and recovers its own solvents for re-use.

H-P-M to Exhibit New Injection Molding Press—418

The Hydraulic Press Manufacturing Company has planned an extensive new press exhibit. This will include the company's latest contribution to the Plastic Molding Industry—the H-P-M Model 25 Injection Molding Press which is being introduced for the first time at the Exposition. This press is the result of three years of pioneering in injection molding in this country by *The Hydraulic Press Manufacturing Company* and is the forerunner of other presses of similar types to complete the range planned for the series.

The H-P-M Model 25 Injection Molding Press is a self-contained and modern machine for the molding of thermo-plastics, such as cellulose acetates into finished articles by the extrusion or injection process.

This machine involves a combination of two major hydraulic members, namely (1) mold-clamping member, with horizontal hydraulic cylinder and double-acting ram with moving and floating die-carrying platens; and (2) a plastic extrusion member, with a second horizontal hydraulic cylinder and double-acting ram actuating the extrusion plunger.

The Carborundum Company Exhibit—91

The Carborundum Company will display their general line of Aloxite Brand Porous Products which includes porous plates and tubes of all types, sizes, and shapes for use in filtration, gas diffusion and separation; "Carbofax," "Alfrax," "Mullfrax," and "Monofrax" heavy duty refractories which are utilized for high temperature, acid-resisting, and heat-conducting applications in the chemical industry will also be displayed.

Alfrax Refractory Laboratory Ware will be on exhibit and a few items made of Zircofrax. These will include tubes, boats, crucibles, thimbles, cones, and various other items.

F. J. Stokes Machine Company Exhibit—80

This exhibit will emphasize pieces made automatically on tablet machines. One of the large *Stokes* #280 Presses capable of producing pieces up to 4″ in diameter will be displayed. This machine is of the toggle type and applies 80 tons pressure. *Stokes* High Vacuum pumps will be displayed. Models will be shown having a capacity of 10 cu. ft. of free air per minute and another of 225 cu. ft. of free air per minute. High vacuum usage is increasing in the process industries, and the pumps exhibited pull a vacuum within a small fraction of a millimeter absolute. Each pump is also equipped with a continuous oil clarifier which removes any moisture from the sealing oil, preventing its re-expansion and resulting in a higher vacuum.

Foster Pump Works, Inc., Exhibit—258

This exhibit will include examples of various types of Rotary Pumps, Vacuum Pumps, and Positive Pressure Blowers manufactured by the *Foster Pump Works, Inc.*

Acid-proof Chemical Stoneware to Be Featured by General Ceramics Company—2

That the many advantages of *General Ceramics* Chemical Stoneware are not limited to a few of the process industries, but are available to practically every process in every plant where corrosion and contamination are production problems, will be a feature of the exhibit of the *General Ceramics Company*.

In addition to an interesting series of actual installation photographs, depicting the wide range of applications of *General Ceramics* Chemical Stoneware, several of the more popular pieces of equipment will be on display.

NEW CHARLOTTE COLLOID MILL

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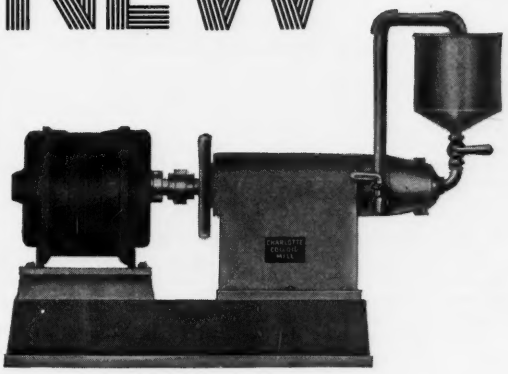

Model #005 Charlotte Colloid Mill is an entirely new development from a mechanical standpoint—far in advance of anything yet accomplished in a horizontal mill.

The new mill uses no stuffing box, therefore no packing is needed. This eliminates a great deal of friction and permits of much smoother operation. The new Charlotte is equipped with oil-less bearings, making constant lubrication unnecessary. It operates continuously with little or no attention—without fear of bearing failures.

This new model will be on display in Booth 237 at the 16th Exposition of Chemical Industries, Grand Central Palace.

In process industries a working knowledge of the colloid mill is essential—in many instances a prerequisite for the job. Let the new model Charlotte Colloid Mill help prepare your students for employment.

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Rochester Engineering & Centrifugal Corporation Exhibit—16

Two outstanding developments in centrifugal history will be featured in the display of the *Rochester Engineering & Centrifugal Corporation*. They will also display a 30″ Bottom Discharge Centrifugal, rubber covered for handling corrosive chemicals and for the separation of crystals from corrosive liquors. Other items include a 48″ Bottom Discharge Extractor in 18–8 stainless steel construction equipped with the Company's improved unloading plow and a 17″ Monex Extractor capable of exerting a centrifugal force of 1500 g., the basket speed being 2750 R.P.M. As accessory equipment a 30″ Bottom Discharge Extractor basket and a 17″ Monex Extractor basket in Monel Metal construction will be shown.

W. A. Taylor Long Range Slide Comparator—337

The Long Range pH Slide Comparator, manufactured by *W. A. Taylor & Co.*, is a portable outfit covering the range of any 3, 4, 5, 6, 7, 8, or 9 indicators between the limits of pH 0.2 and 13.6. It contains a complete Slide Comparator, the base of which fits into a compartment in the front of the case; 2 to 8 extra color standard slides, contained in two compartments in the back of the case; vials of the corresponding indicator solutions with pipets and nipples; and 145- cc. test-tubes.

J. Bishop & Company Exhibit—487–488

J. Bishop & Company Platinum Works will display its full line of products. This will include platinum laboratory apparatus, micro apparatus, and spinnerettes for the rayon industry. Catalysts of platinum alloys will be on display, as well as a line of precious metal salts, together with rhodium plating solutions.

The Cuno Engineering Corp. Exhibit—248

This exhibit will include various models of the *Cuno* Flo-Klean Filter. This type of filter is a new development in filtration equipment designed to handle the filtration problems not readily solved by filters now on the market. It has been developed to remove solids from fluids where the solids are highly abrasive in character. The *Cuno* Flo-Klean filter is self-cleaning and need never be stopped until the normal shut down period of the process involved is reached.

Chemicolloid Laboratories, Inc., Exhibit—237

Chemicolloid Laboratories, Inc. will display a new laboratory model colloid mill. The new model #005 Charlotte Colloid Mill has no stuffing box, and, therefore, does not employ packing. This will eliminate a great deal of friction and make for much smoother operation. Other features have also been added to make this model more convenient to operate.

LUX Fire Extinguishing Equipment—504

Visitors at the chemical show will be interested to see for the first time the complete new line of *LUX* fire extinguishing equipment on display. They are manufactured by *Walter Kiddie & Company*. These *LUX* portables range in size from 2 to 100 lb. gas capacity. The carbon dioxide is stored in liquid form and expands 450 times to a blanket of snow and gas when released from the cylinders.

Alberene Stone Corporation of Virginia—79

The *Alberene* exhibit will consist of an *Alberene* Stone sink with drainboard and pegboard; also an *Alberene* Stone table with the *Alberene* Stone shelving. An all-stone hood with the stone superstructure and baffle will also be exhibited.

A table top made of Virginia Black Serpentine will be shown. This stone will be particularly interesting to those whose primary interest is fine finish and appearance in laboratory tables.

Glyco Products Co., Inc., Exhibit—219–220

The *Glyco* exhibit will include various products which have been developed commercially since the last Chemical Exposition. Glycoride (Glycol Glyceryl Stearate) is suggested for paste emulsions for cosmetics, polishes, textiles, leather, paper, etc. Polyrin (Glycol Glyceryl Laurate) is suggested for emulsions for use in cosmetics, leather, textiles, paper, and the like. It also has interesting properties as a dry cleaning soap base. Abopon (complex sodium boro-phosphate) may be used in adhesives, paper, cosmetics, polishes, textiles, shoe dressings, paints, fireproofing, etc. Foamex is suggested for the manufacture of paper coatings, latex compositions, leather finishes, adhesives, textile sizes, and finishes.

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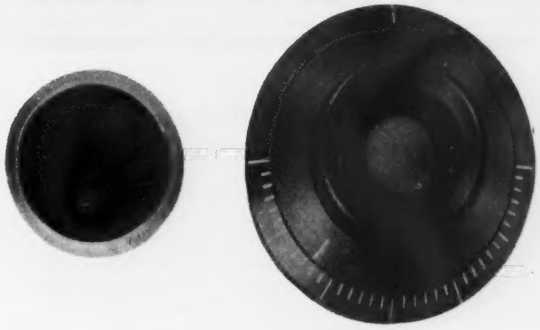

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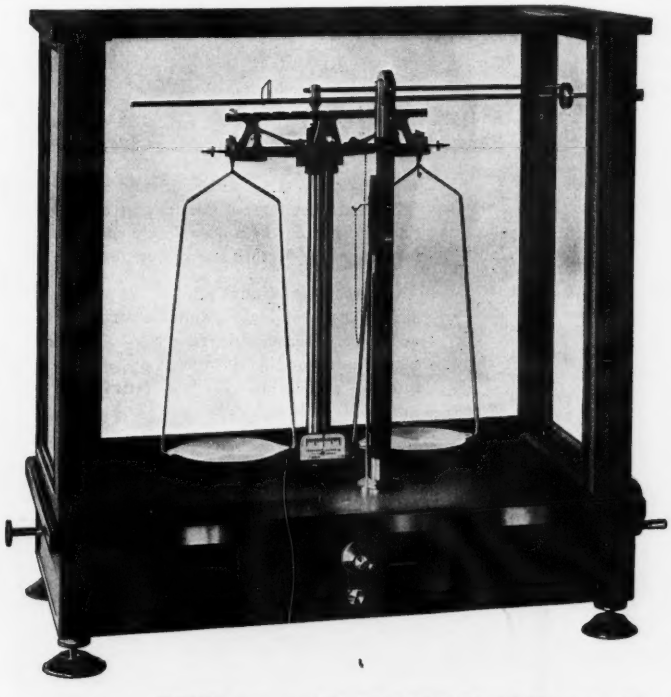

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THIS splendid suggestion, presented by Dr. E. H. Huntress, of the Massachusetts Institute of Technology, in an article in the July issue of the JOURNAL OF CHEMICAL EDUCATION, seemed so valuable that an edition of reprints was run to make it more easily available to chemistry teachers.

A list of the anniversaries of well over 1000 distinguished contributors to chemistry is offered by Dr. Huntress "with the belief that by appropriate use of opportunity the material can be used as a teaching tool."

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THE report of the Committee on the Correlation of High-School with College Chemistry forms a 12-page leaflet containing a revised list of essentials for the help of high-school teachers of chemistry.

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The *Premier Mill Corporation* display will include a 3″ Belt Driven Laboratory and Small Production Unit, a 3″ Direct Connected Unit, a 6″ Direct Connected Paste Type Mill and a 10″ Direct Connected Paste Type Mill. Samples of products made on *Premier Mills* will also be exhibited.

Kimble Glass Company—342–343

The *Kimble Glass Company* will exhibit a full line of Exax, Normax, and Kollegiate Graduated Laboratory Glassware, as well as the Kimble-Brand Lamp and Mould Blown Ungraduated Glassware.

New Dustless Weighing Hopper—564–569

A new dustless weighing hopper, furnished with or without a weighing device, for handling all kinds of powders, such as required for manufacturing drugs, cosmetics, paints, chemicals, etc., has just been placed on the market by *Read Machinery Co., Inc.* It will be exhibited.

"Hurricane" Drying and Finishing Machinery Exhibit—563

This exhibit, which is sponsored by the *Philadelphia Drying Machinery Company*, will consist of illustrations of the latest improved equipment for drying, baking, and processing chemical and pharmaceutical products.

Hercules Powder Company Exhibit—W–7

The *Hercules* exhibit will consist of paint and varnish vehicles, lacquers, adhesives, and insect spray materials.

A New Electrostatic Precipitator—75

A new electrostatic precipitator for general industrial air cleaning use with an operating efficiency as high as ninety-nine per cent. by weight is announced by the *Pangborn Corporation*. The unit is particularly suitable for salvaging valuable dust, mass air cleaning, or removing objectionable particles from gas or vapor and similar applications.

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Haynes Stellite Company to Exhibit at Chemical Show—77

Haynes Stellite Company, unit of *Union Carbide and Carbon Corporation*, will exhibit Hastelloy alloys for corrosion-resistant chemical plant equipment.

Numerous castings of Hastelloy alloys A, B, C, and D, and forged or rolled products of Hastelloy alloys A and B will constitute the major portion of the Haynes Stellite exhibit. Parts cast or fabricated of Hastelloy B, the new alloy for service in hot hydrochloric acid, are to be featured.

Valves, pumps, and other equipment protected by a welded-on wear-resistant layer of Haynes Stellite will also occupy a portion of the exhibit. In this group, the central attraction will be Haynes Stellited valves for lines handling high-temperature, high-pressure steam, or mildly corrosive media.

Industrial Chemical Sales Exhibit—87–88

The *Industrial Chemical Sales* exhibit will include "Nuchar" Activated Carbon. It can well be called a modern purifier in the process industries. The results are accomplished by adsorption, thus actually removing impurities from solution instead of accomplishing the improvement by chemical change. "Nuchar" Activated Carbon is used to remove objectionable colors, flavors, odors, and other impurities from solution and is utilized in the purification of many food, chemical, drug, and pharmaceutical products.

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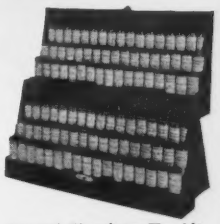

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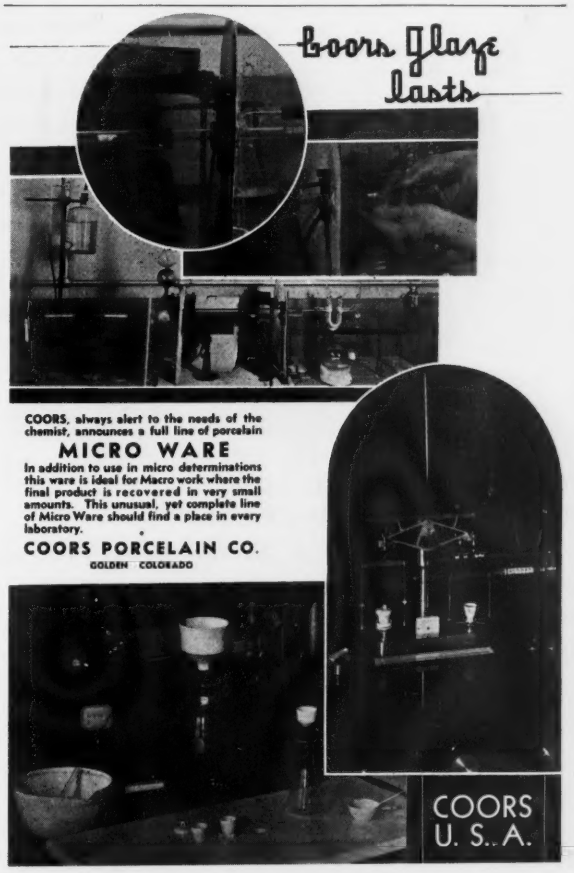
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The Alkaline Earth Metals and Magnesium and Cadmium.
Elements Isolated with the Aid of Potassium and Sodium.
Some Spectroscopic Discoveries.
The Periodic System of the Elements.
The Rare Earth Elements.
The Halogen Family.
The Inert Gases.
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Recently Discovered Elements.

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